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NOTES

ACHIEVING WORKER MOTIVATION FOR A SUCCESSFUL INDUSTRIAL ENGINEERING PROGRAM

by

David H. Nicholson before the Sixth Annual National Conference of the American Institute of Industrial Engineers in St. Louis, May 12, 1955.

In the Gilbert and Sullivan operetta, "The Pirates of Penzance", most of you remember the ditty, "A Policeman's Lot is Not A Happy One". Whether or not you agree with Gilbert and Sullivan in their comic interpretation of the lot of the hapless policeman, I think you will agree with me that the lot of the industrial engineer is neither a particularly happy nor an easy one. The profession of industrial engineering combines some elements not ordinarily found in the other engineering professions. The research engineer has his laboratory - in the privacy of that laboratory he works undisturbed by the outside world, concentrating on the problems of research. The civil engineer's job is to build bridges, lay sewers and water pipes, or to construct highways. If the highway is not laid out where the citizens of a certain community would like to have it, they don't take out their enmity on the civil engineer. He is a technician. They vent their wrath on the State Highway Commission. The holy of holies of many manufacturing concerns is the development engineering laboratory where goes on the creative work of the design and product development engineering staff. These fellows are provided with their private quarters and for the most part are left undisturbed while they dream up the "gadgets of tomorrow". Oh yes, these fellows get plenty of criticism from the manufacturing department but the insulation surrounding their laboratory protects them from most of this fire. The ultimate consumer who tries to use the issue of their creative brains damns vehemently the manufacturing department for turning out such a lousy product.

The industrial engineer has no laboratory into which he can retreat or in which he can work in privacy. Neither is the industrial engineer surrounded by the cloak of professional respect and austerity accorded to some of the engineering professions. For the most part the industrial engineer must work in the front lines, surrounded by the victims of his engineering efforts. For him there is no escape.

In spite of the difficulties of your job, industrial engineers have made tremendous contributions to the progress of American industry. In collaboration with industrial management you have taken manufacturing out of the little shops and attics of colonial days into the modern American industrial factory which is the envy and the marvel of the entire world. I'm not going to say that the industrial engineer is 100% responsible for the industrial revolution. However, no one can deny that mass production

as we know it today has been achieved in a great part by improved operating methods, by mechanization of procedures, by efficient office and factory layouts, by improved office and factory work flows, by the study of and improvement of material handling and material storage, by the study of work methods and operations and the analyzation of time and motions required to perform these operations, by the design of worker incentive plans whereby the worker has been rewarded for his own and his team's productivity; by all of these efforts of the industrial engineer co-ordinated with the efforts of management and with the other branches of engineering the marvel of American mass production has been achieved.

Industrial engineers have been immensely successful with the technical phases of their work but they have been plagued with failure by not getting work acceptance of the goals of industrial engineering. The achievements of the industrial engineering profession, however magnificent, have been attained by the most part over the protestations and resistence of the laboring force. Most of us have heard of plants where the workers have joined hand in hand with the engineers and with management, marching forward progressively toward the achievement of the goals of the organization. These stories of collaboration are certainly the exceptions rather than the rule and tend to prove the rule that workers have been exceptionally suspicious of the motives of both management and of industrial engineers, and step by step down through the years have resisted the efforts of both management and of the members of your profession.

In many instances, this resistance has gone to the point of sabotage. In most cases the resistance has been of a more subtle nature and perhaps more effective because of its subtlety, retarding and harassing the industrial engineering program. Opposition of an antagonized work force has hampered your efforts in the great majority of American factories. This resistance has come to public attention when the unions have taken their workers off their jobs in outright opposition to your program. However, as you engineers know, most of your programs have either been defeated or greatly handicapped by the failure of the working people to support and cooperate with your efforts.

It is not my intention to portray an altogether hopeless situation. The wonder of it all is that you have achieved tremendous progress in spite of the lack of worker support. Of course, the degree of worker collaboration and cooperation varies to a great degree from plant to plant and from industry to industry. In some situations the industrial engineer has achieved worker support for the attainment of his goals in spite of stupid management. And, I must confess that in still other plants, management has achieved a rather remarkable degree of worker support in spite of industrial engineers.

From an over-all point of view our weakest job has been in the area of securing worker collaboration in the achievement of the goals of the company. Productivity is the ultimate goal of management and it must be the ultimate goal of industrial engineering. Anything that hampers productivity is to that extent a failure attributable to management and to industrial engineering. Neither management nor the industrial engineer can alibi for his lack of success in attaining productivity by blaming the other party. It is true that management must accept the ultimate responsibility for not attaining its goal of efficient operation at a profit, commensurate with the needs of the concern. Management has hired industrial engineers to bring about improvements in a plant layout; to improve its operational methods; to simplify its work; and to increase its production at lower costs through more effective worker incentives. To the extent that the industrial engineer has failed in his efforts to help management achieve these goals he must be held accountable.

The industrial engineer cannot confine himself to the technical aspects of his job. History has shown us that methods can be studied and can be improved; that materials can be efficiently handled and stored; that offices and plants can be laid out and systems can be devised which will produce products and services in a highly effective and efficient manner so that these products and services can be distributed to the consumer at reasonable prices so as to maintain the business and meet the costs of operation with a profit to the stockholders who have invested their money in the concern. When a large group of the participants in this multiple effort not only do not accept the goals of the management but openly or privately interfere with the achievement of these goals, then the responsibility for this failure of collaboration must rest with the industrial engineer to the extent that he has failed to secure collaboration for his program. If the industrial engineer is to succeed, he must succeed in all phases of his work program. Securing the cooperation and support of the workers for the achievement of his purposes is a necessary part of his job. The industrial engineer is in almost daily contact with the work force. This greatly increases the difficulties of his job, as I have said, but it also presents to him the opportunity of persuading the workers to accept his point of view and to give to his efforts the support necessary for its success.

We are standing today on the threshold of the second industrial revolution. This new era in industrial development has been variously described as the age of automation, as the atomic age; the era of the high speed calculator and the servo-mechanism. The potential of our technical development is breathtaking and beyond the realm of imagination. But, our greatest opportunity for improved economic performance does not lie in automation but in the improvement of the effectiveness of people in their daily work. The success of industry in the future can to a great

degree be measured by the ability of its management to get people to perform at a high effective work level.

Some say that animal strength is becoming less and less vital to the success of the business enterprise. I agree, but we haven't been using brute strength divorced from intelligence and judgment to any extent in our factories for many years. The unskilled laborer hired yesterday has become today's semiskilled machine operator who has to exercise in the course of his duties a fair degree of critical judgment. He may exercise this judgment in a repetitive manner but when he tends his machine, feeds in material and inspects the product, he is exercising considerable control over the quantity and the quality of the product of his labor. Since the employee does not work as a hermit in any isolated cave, his efforts must contribute to the program of the whole plant, contributing to its morale, to the rhythm of its production and to its ultimate success or failure.

As we move deeper into the new era of technology, it is certain that the output of goods will increase in relation to the number of people required to produce these goods. As we decrease the number of people on the factory floor, we will greatly increase the number of people working to maintain machinery, directing the flow of work, inspecting and measuring output. The relationship of these people to their machines and to their processes; to each other and to the organization as a whole becomes more critical as their numbers decrease. We would indeed be nourishing a fool's paradise if we entertain for one moment the idea that with technological advances the human factor will become less and less vital to the success of the enterprise. The factory of tomorrow will place more and more responsibility on the shoulders of the industrial engineer and to a greater degree than ever his effectiveness is going to depend upon his success in securing the support and wholehearted collaboration of those people who work with him in every capacity in the organization.

Before we can make progress in the development of a plan to achieve worker motivation for any program, we must attempt to determine why we haven't been successful in attaining worker support in the past. Where have we made our mistakes? And what mistakes have we made? Unless we can be objective about examining the record then there is no hope whatever for improving that record in any respect. Before we can achieve worker motivation, we must undertake to secure some comprehension of the problem involved. There is no magic secret formula by which we suddenly attain social mastery of a situation.

The planning of human relationships is a difficult task - the achievement of such a relationship is a still more complicated undertaking. It can never be achieved by the use of gadgets or

special techniques nor by a 10-week training course meeting two hours per week under the direction of the training director. Achieving human motivation is a long-time program involving a great amount of personal effort. It requires careful scrutiny of our own objectives, our own personal motives and procedures. Recent scientific writings in gardening have begun to recognize that perhaps the most serious pest in the garden may be the gardener. The industrial engineer himself may have been his own worst enemy to his own program.

Professional industrial engineering has taken cognizance of the need for being able to work with people. For a number of years now our leading colleges have offered courses in psychology and industrial management and in other social sciences as an essential part of the education of an industrial engineer. If these courses have been to any degree effective, the industrial engineer has had an advantage in the battle to achieve human motivation over other engineers whose training has largely been confined to the technical aspects. Whether or not these courses have been successful, they have at least given recognition to the problem of human relationships as a vital aspect in the functioning of the engineer on the job.

As a rule, engineers as a professional group tend to be interested primarily in technical things. They are inclined to concern themselves with material resources rather than human resources. The industrial engineer may have to recognize that his own personality and his own specialized interests and self engrossment may actually hinder his achievement of motivation of workers.

A few weeks ago a young methods engineer startled me by asking this question, "How can I become personally more convincing?" Everything that I could possibly say in this talk on achieving worker motivation is wrapped up in that single question. That young engineer had made real progress when he perceived that he was lacking to some extent in the ability to persuade people to accept his point of view and to wholeheartedly subscribe to his objectives to the point of supporting him in their achievement. Let me assure you that I was unable to give him a 10-minute answer to his question. The whole problem of achieving human motivation is so complicated and involved that no individual can possibly come up with the answer. It is a problem of such proportions that it would be worthy of a lifetime of work of a laboratory filled with human engineers devoted to the solution of the problem. But the problem is not going to be solved in an isolated laboratory. It is going to be solved by such men as yourselves who are out on the firing line rubbing elbows with people.

One grievous error we have made in the past is in forming the wrong concept of workers. It seems to me that we have gone the

easy way by thinking in terms of workers as a group or as a class. When we think of people as a group or as a class, we automatically put the group into a majority and we put ourselves in the minority. On the surface this may seem to simplify the problem but minorities are usually defensive and aggressive and are ordinarily resisted by majorities. Many an industrial engineer has told me that he felt as if he represented the voice crying in the wilderness. What he really meant was that he visualized himself as a minority espousing the cause of management and of progress. This may give one some personal satisfaction but it is a highly faulty concept of a human relationship. People are people regardless of their occupation and economic and social situations. You can't tackle this problem by attacking the group. If you do, you are outnumbered from the beginning. The whole basis for attacking the program is from the viewpoint of an individual day-to-day contact.

How can you become personally more convincing? To whom? Well, the man on the machine or to the woman at the assembly bench - that is a tough problem but it is relatively simple as compared with becoming more convincing to an organized group opposed to my objectives. So part of your problem is how can you get Joe to accept you and your job? How can you get him to help you make a success of your work? You, as an industrial engineer, are an advocate of change - the basis for your whole program is dissatisfaction with the status quo.

But people are defenders of the status quo. Change threatens our security so few of us welcome change. If that were the case the human race would still be living in caves and eating their meat raw. It is dangerous nonsense to believe that people don't want to change. Human beings are hungry for new things and new ways of doing things.

Well, why then is it so difficult to get the worker to go along with the changes you recommend? Just as you have personal motives for doing whatever you are doing, so the worker has personal motives. One of the primary objectives which every worker has is to protect his own personal security. He has been taught since childhood to stand on his own feet and that every man must look out for himself.

In order to get the worker to support your program you must first understand his motivation. You have to know what he wants to get out of life. He knows that you want him to change and he has a healthy suspicion that in the process of the change you propose, the management of the company will gain and he, the worker, will lose. In all probability he understands your goals better than you understand his. He knows that you want higher production, that you want more efficient production, that you want to reduce scrap, that you want to improve the quality of the

product or the service. He the worker is quite certain that whatever your goals are they are primarily intended to satisfy the over-all objectives of your employer.

He knows that you personally have an ambition to succeed as an industrial engineer. He may suspect that you have an ambition to advance yourself in the organization - up the ladder of management. If you have not told him anything to the contrary, he may well suspect that you intend to achieve your personal goals and the goals of the organization pretty much at his expense. But you say that is not my intention - my intention is to improve the productivity of the whole organization and everyone here will benefit from it.

True, we are going to make progress by mechanization, by more automation, by improving our present methods and machinery, which means that you as you establish yourself as a successful industrial engineer want more and more for less and less. You want more products for less effort with greater efficiency and less cost. Put yourself in the work shoes of the man at the machine, and perhaps you can see that back of this program, lurking in the shadows, is a threat to the worker's personal security.

In the years that he has stood at his machine he has seen the demand for higher productivity become more and more pressing. He has seen more and more pieces turned out with fewer and fewer people - he probably has seen people laid off as efficiency improved, and he has seen other people bumped down the line to less technical jobs. If he hasn't experienced this himself, he has heard about it or he has read about it. He has been told by his union leaders that only by banding together in a strong union represented by intelligent, aggressive leadership can he hope to protect his rights against the monster of management. And because the worker wants more and more for less and less, just as you do, he has gone along with the philosophy that by organizing and resisting he can protect himself, enhance his own security, increase and protect his paycheck. Through his union he hopes to build a hedge against the threat of an uncertain future. His union leadership has indoctrinated him with the idea that you get only what you fight for and management to a great extent has fostered this idea, too.

You don't have to go to college to find out what the worker wants. If you will listen, he will tell you what he wants out of life. He will tell you that he wants security for himself and his family; that he wants to pay off the mortgage; that he wants to drive a nice car; that he wants to raise his family in a nice neighborhood; and he wants his kids to have the advantages which his neighbor's kids have. He wants to dress his children as well as the man next door and he wants his family to enjoy the benefits of the community. He wants his children

to have a better education than he had - and he doesn't want them to have to quit school to help support themselves and the family. Personally, he wants to know that he has a chance for advancement in this outfit if he decides to take advantage of it. If he doesn't want to use that opportunity, he wants to know that it at least exists for those who do have what it takes to advance. He wants some personal recognition for the job he is doing and he wants to feel important as an individual. Most of all he wants a fair deal from his boss and from all other representatives of the company.

In an article by Kenyon and Helen Runner, entitled,"Personality on the Job", appearing in the December, 1954, issue of the magazine, Adult Leadership, we find a report of an attitude study of a plant of 300 people in a small town industry.

"The employees are people who want a well defined work situation in which they are always sure what to expect and what is expected of them. They are conformists in their thinking, accustomed to following the patterns of thought and activity established by their own social group. They are cautious, unimaginative folk, primarily concerned about doing things right, earning a decent living and getting along peacably with other people. The injection of an independent thinking, individualistic person into this group always presents problems."

You, as the industrial engineer are the independent thinking, individualistic person, coming into this neat little social group. As you become better acquainted with a worker and his objectives you will find less and less to take issue with about him and you will probably find yourself coming to the conclusion that he is a pretty good guy after all, pretty much like yourself. And in this respect you are wholly right and have taken the first step toward solving your problem of achieving motivation.

As you get better acquainted with this worker at the machine you find that he is an ordinary human being, not opposed to change for change itself. He is opposed to change from the known to the unknown. The change proposed must appear rational to him - it must appear as something better than he has had before. Since the worker wants to know what to expect and he wants to be sure of what is expected of him, the change must come slowly and it must be accompanied by information - reasons justifying the change which he can comprehend. None of us want to be shown up - most of us have an underlying fear that somehow we may not live up to the expectation of others. If you are to be successful in achieving motivation your workers must think that the job, as you propose it to be, fits very well within their own feelings about what they can do and what they want to do.

Workers as a general rule are quite sensitive people. Their sensitivity is usually hidden by a rough exterior. Remember, however, that this outer veneer is exceedingly fragile. In their minds, you, the industrial engineer, with your college training, your kit of tools, and your company backing, have a decided advantage. They try to offset this seeming advantage by resistance.

As engineers, it is your professional habit and responsibility to find out what is wrong with me and my work situation. If you ask me what my faults are, if I happen to like you and trust you, I may tell you. But don't you tell me my faults. For if you do, I won't give you a straight story and my resistance to you will increase geometrically.

It is a false assumption that people enjoy being wrong. No one outside of a mental institution wants to do a weak or inferior job. Some engineers seem to enjoy proving that they are right. In the course of proving yourself right, if you should prove the worker wrong, you will have lost his confidence forever. The Oriental has no monopoly on wanting to save face.

One of our difficulties in the past is that we have given people altogether too little information. We have assumed that people should go along with the program of the organization on the basis that it was good - that what was fundamentally good for the organization was fundamentally good for the worker, and that he should have faith in the management and accept it. It hasn't occurred to many engineers or to management, either, for that matter, to take the people into their confidence. However, in recent years considerable progress has been made in this connection. We have heard a great deal about telling the management story. Some of this has actually slipped into practice so that we are now giving people more information about the purposes of the company and the particular and immediate goals. Of course, it isn't necessary to tell everything, but it is necessary to give the worker a basis for understanding your program and its objectives and particularly how these objectives and goals are going to affect him.

In the animal kingdom it is said that the animals have one day set aside as Brotherly Love Day. On that day no animal harms another. On a certain Brotherly Love Day, the little rabbit, drinking at a pool, saw a shadow fall across the water. Looking over his shoulder, he saw a tiger and immediately ran as fast as he could. The tiger called after him, "Why do you run, little rabbit? Don't you know that this is Brotherly Love Day?" "Yes, I know", called back the rabbit, "but there is always some S.O.B. who doesn't get the word!"

This imparting of information is only the first step. You want the worker to feel differently about something - you want him to do something differently, something he has not done before. Or

you want him to do something he has done before in a different manner. To bring about these changes we must first ascertain our present situation - what is wrong with our procedures and out attitudes and our feelings?

And then we must determine the changes that we hope to achieve in procedures, attitudes and feelings. We must be mindful that our own procedures and attitudes and feelings need to be studied just as the workers' procedures, and attitudes and feelings need to be studied. Did you, as an industrial engineer, ever job-study yourself? It would be a most worthwhile project and should be quite enlightening.

It is seldom wise for us to be dead sure of ourselves. Underneath things are not always what they appear to be on the surface. For instance, take the foreman who has the highest costs in the whole shop. Does he need a cost reduction program including cost reduction training? Taking a look at his whole department, suppose you find that his employee relations smell. He always says the wrong thing. You can teach him cost reduction without solving the problem because you are not treating the basic cause of his difficulty.

Anyway, after determining the changes we hope to make, we must proceed with the supplying of information. Motivation doesn't begin until first we show the reasons for the changes that we expect to bring about. We must show that the changes we propose are reasonable and they must be made to seem reasonable to the worker. A very good test of law is what a reasonable person would be expected to do under similar circumstances in a similar situation. So the test that we apply to the workers is a test that a good jurist applies in court. What is reasonable? Is the proposed change clear? Does it strengthen the worker's security or does it make his position all the more precarious? Does the proposed change require some positive action on his part?

If you have not clearly defined your objectives and the changes that you propose to make, then it is not unreasonable to expect that the worker will assume that you want more and more from him for less and less which is in direct contradiction with his own personal objectives. As he sees it then, your goals threaten his own security and the realization of his own personal aims and ambitions. Why then, should he give you his allegiance and his support?

Theory which seems to have little relation to the problem at hand probably bores most of us. And that's why we have trouble sizing up the human factor because it is intangible it can't be placed under the microscope. It has to be felt rather than seen. It does not lend itself to measurement. Objective appraisal is

difficult. The industrial engineer undoubtedly occasions difficulty in his contacts with supervisors and higher level management as well as with the workers. In all of these contacts it is important to remember that interactions between people that are heavily weighted with one side initiations are likely to be trouble spots.

Writing in the Michigan Business Review of November, 1954, (published by the School of Business Administration, University of Michigan) Leonard R. Sayles, Assistant Professor of Industrial Relations at the University of Michigan, says that in these human interactions, the person on the "giving" end of the relationship is in quite a different position psychologically from the one on the "receiving" end.

One team of researchers has recently come to the conclusion that the foreman-worker relationships tend to be better in departments where the quality is less subject to worker control and is more machine determined. Under these circumstances there is not the necessity for constant foreman-worker contact and since these contacts involve initiation by the foreman, the superior in the organization, the number of "ordering" initiations, foreman-to-worker, is reduced. The industrial engineer is in the unfortunate situation of frequently initiating most of the human interactions and seldom being on the receiving end of the relationship. For this reason, I have been recommending in this paper a somewhat more informal relationship with the worker - a relationship which would involve more listening on your part and less giving or ordering.

I know of no evidence which indicates that this would weaken your position, but I am sure that there is abounding evidence that it would strengthen your situation so far as your relationship with the individual worker is concerned. If you go home from this convention and start to listen in your own plant, you may find some startling ideas are held about the company's goals, particularly about your own goals. You will probably find that they are quite perverted, mistaken, misconstrued, but before you condemn, first consider the sources of their information. Have you attempted to present your side of the story?

Your job is primarily first to clearly delineate the aims and objectives both immediate and far-reaching of your company as they apply to the industrial engineering situation at hand, and, second, to show to the worker how the achievement of these goals will help him to advance his own personal interests and ambitions and security, and will in no way be in contradiction to his personal aims and objectives. If you find it difficult to do this job, then you better gird yourself and strengthen your own resources because this is the task that lies before you.

In American industry these past 25 years we have made a fetish of specialization. You industrial engineers have been highly successful in analyzing operations. You have reduced the job to its simplest component. The tragic mistake which management has made has been to buy your package in its entirety. Work simplification is wholly commendable but worker simplification has deadening results. Breaking a job down to its basic elements does not mean that each tiny component of the job has to be performed in its entirety by a single worker. We have spoken of the worker as a human resource. Certainly we haven't exhausted the potentials of this human resource when we ask the man to put the tap on a certain screw. In using a resource we have to study the resource in all its aspects. Human beings have many capacities and have much to offer. It is very difficult to motivate the worker who is retained at a job level below his capacities.

Placement of the worker on the job is a management function and not the function of an industrial engineer. However, the industrial engineer should have influence with management. The work of some industrial engineers places them in close contact with workers. Some of you have the opportunity to observe workers more closely perhaps than their own supervisors. It seems appropriate to me that you might make suggestions to the supervisor when you have observed workers who show considerable promise to handle tasks beyond their present work assignment.

In his recent book, The Practice of Management, Peter Drucker devotes a chapter to the International Business Machines Corporation story. According to Mr. Drucker, IBM has adopted the policy of "maximizing jobs" in order to create significant job opportunities for semi-skilled workers. According to Peter Drucker, each job at IBM is designed so as to always contain a challenge to judgment, and an opportunity to influence the speed and rhythm of his work. I quote from Drucker's book: The Practice of Management.

"The story goes that Mr. Thomas J. Watson, the company's president, once saw a woman operator sitting idly at her machine. Asked why she did not work, the woman replied: "I have to wait for the setup man to change the tool setting for a new run." "Couldn't you do it yourself?" Mr. Watson asked. "Of course," said the woman, "but I am not supposed to." Watson thereupon found out that each worker spent several hours each week waiting for the setup man. It would, however, only take a few additional days of training for the worker to learn how to set up his owr machine. Thus machine setup was added to the worker's job. And shortly thereafter inspection of the finished part was included, too; again it was found that little additional training equipped the worker to do the inspecting."

"Enlarging the job in this way produced such unexpected improvements in output and quality of production that IBM decided systematically to make jobs big. The operations themselves are engineered to be as simple as possible. But each worker is trained to be able to do as many of these operations as possible. At least one of the tasks the worker is to perform - machine setting, for instances - is always designed so as to require some skill or some judgment, and the range of different operations permits variations in the rhythm with which he works. It gives the worker a real chance to influence the course of events."

"This approach has not only resulted in a constant increase in productivity at IBM, but has also significantly affected the attitudes of workers. In fact, many observers both inside and outside the company think that the increase in the worker's pride in the job he is doing is the most important gain."

Too many of our companies have adopted from the automotive industry the principle of one motion to the worker. As Drucker indicates in his book, this may be an effective principle on the automobile assembly line, but the production of one basically uniform product exists in few other industries. A few companies have been experimenting with the multiple operation principle and have found as a result productivity has gone up, turn-over of employees has dropped and the quality of the work has not suffered. Drucker cites the example of a mail-order plant in which the work had been organized by individual motion.

"One clerk answered complaint letters, another one inquiries, a third correspondence on installment credit, and so forth. Each only handled what could be answered by printed form letter; the few letters that required individual handling or judgment she passed on to the supervisor. Now each clerk handles all correspondence with a customer -- all customers whose names begin with the letter "A", for instance. Nine hundred and ninety-eight out of every thousand letters still are answered by form letter. And there the work itself is as fully engineered, as fully predetermined, as fully laid out - and as repetitive - as before. But instead of repeating one particular motion again and again, each clerk now handles the entire range of motions - thirty-nine to be precise - involved in routine relations with the mail-order customer. And while the rare letter that requires judgment is still not answered by the completely unskilled clerk, she is supposed to write on it her suggestion how to deal with it before handing it to her supervisor. As a result productivity has gone up almost 30 per cent; turn-over of clerks has dropped by two thirds."

As Drucker suggests, whenever the one motion one job concept can be used most effectively we have an operation that can and should be mechanized. Work that can best be handled by the one motion principle should therefore be engineered as work of

machines rather than of men. For all other work, and that means for most of the work done today in manufacturing industry and for all the work that will be created by automation, according to Drucker, the principle is the organization of the job so as to integrate a number of motions or operations into a whole.

To my way of thinking, this offers a tremendous challenge to the profession of industrial engineering. While you may not be in the business of designing new production machinery, you certainly are in the business of making systematic analysis of work into its constituent motions. It is your job to lay out the work in a logical sequence of motions. By integrating operations you will utilize the wider skills of the employee, including his judgment and his ability to make decisions and encourage him to offer suggestions and to assist you with the planning of this integration program.

Industrial engineering has done a wonderful job in dissecting the job into parts or motions. Your new task is to put these parts together into an integrated whole. Through this process we can readily visualize that each job should not always depend for success on the current speed and rhythm of the performance of the worker. Neither should it be dependent on the speed with which the job before it is being done. By doing a sequence of operations the worker is able to vary his speed and should not be put under pressure if he does the work a little faster and at other times a little slower. Some exercise of intelligence and judgment and challenge should be left in every job. The level of skill and judgment needed, of course, will vary according to the kind of work and the level of difficulty.

Drucker suggests that in general we can say that the more manual skill is required in an operation, the fewer basic steps should be integrated into a job. The more judgment required, the more basic steps belong together. People work well as individuals or in groups as a team. These examples which Mr. Drucker has cited would seem to indicate that people do not work best when organized like machines in the traditional way linked in a series.

Effective organization of employees into work teams has much to offer in the way of motivation of the worker. Group incentive systems generally have proven satisfactory. Many people, who are not driven to higher productivity by individual personal rewards, will work at the higher productive level and earn their higher personal income when they are members of teams, under the pressure of the group. Groups always develop into social units with the attending values of group pride, morale and spirit. The work of the group should be so organized that the achievement of each individual benefits himself and the group as a whole, and result in greater individual and group productivity.

Properly developed, group incentive systems seem to have been somewhat more effective than the individual incentive plan so far as motivation of the worker is concerned. A common criticism of incentive plans is that the norm set up for a day's performance is a minimum standard which neither interests nor challenges the efforts of the more able individuals in the department. I do not propose to be well informed on incentive systems but I cannot help but question the principle of paying 125% of a day's pay for one day's work. Unless the worker is willing to perform better there seems to be considerable question whether the individual incentive plan really provides the most desirable basic motivation.

The whole question of the influence of monetary rewards has been under debate for a number of years. In a number of surveys which have been taken in industry, few have found the workers listing financial reward as their first incentive. Everyone knows that monetary rewards are necessary and must seem fair and equitable, but it is doubtful if compensation has played as important a part as we have been inclined to believe in the past.

In my earlier professional life I worked as a teacher and as a public school administrator. Since leaving active school work I have maintained a close interest in education. I have never seen a classroom where the teacher set low standards of performance and achieved a high level of learning. High standards of performance are essential to the proper motivation of the worker in industry just as in the classroom. A job that makes high demands on the employees challenges them to effective production. Low or mediocre work standards neither interest the worker, nor gain his respect for the plant management. Of course, I do not mean to infer that if you try to change low standards of productivity to high standards that you will not meet with protestations and resistance.

During World War II because of the shortage of industrial engineers and because of the importance of improving job methods as well as the necessity to train many new workers and new supervisors, most of the industries of the country instituted some type of job method study. In plants where the industrial engineer worked hand in hand with the supervisor in improving the methods of operation, effective results seemed to be attained . . . . certainly much better results than where the engineer worked independently of the supervisor. This same cooperative principle has been used successfully in recent years by some industries in securing the cooperation of the workers in actually assisting in the job planning. There is considerable evidence to sustain the point that a better job of planning is done if the man at the bench or at the machine is invited to participate in that planning. Not only has better engineering of the work resulted, but better work performance has been secured and there

has been a remarkable lessening of resistance to change. Altogether too few examples of worker participation in the program of job improvement are on record. After all, who is in a better position to suggest changes or improvements than the man on the job, and who is most apt to benefit by job improvements which make the work less arduous than the man performing that work. An invitation to participate is one of the best techniques for motivation of workers.

In some companies joint job study or time study teams with union representatives have shared in evaluation work. This is a form of participation which may be worthwhile in some situations and may be a real cause of trouble in other places. I do not feel competent to comment on the practice because blanket endorsement of any given technique is dangerous.

My recommendation is to establish the proper working relationship between the workers, their union, and you . . . then develop the practices and techniques which are consistent with your experience in your own situation. Be very slow to adopt a packaged plan. Do your own thinking. You are the best judge of the program which will work in your company. Because a certain technique is supposed to have been successful in the Ajax Corporation, it does not follow that you should give it a whirl in your place. Let us hope that your doctor does not treat your appendicitis in the same manner as he does my broken leg.

Giving the worker a stake in the business through profit sharing has proven in many companies to be a powerful incentive for higher productivity, for lower turn-over and higher general morale. I will not elaborate on profit sharing as it relates to the motivation toward acceptance of your industrial engineering program. I cannot speak on that point but I am confident that profit sharing does improve worker productivity and tends to hold it at a higher level. It gives the worker a stake in the whole enterprise and an interest in the welfare of the company as a whole. Anything which accomplishes that must be worthwhile.

I realize that some of these proposals fall in the line of management responsibility rather than immediately as a task of the industrial engineer. However, I propose them in the hope that industrial engineers in their professional capacity will come to view their jobs in a wider concept than heretofore. Not only industrial engineers but foremen, plant superintendents, personnel directors and department heads everywhere need to get a wider understanding of the company's place in the industry and need to gain a more fundamental concept of the relationship of of their job to the total program of the organization. The worker needs this concept of relationship of his job to the total enterprise. He cannot gain that from industrial engineers and from supervisors who do not themselves hold that concept.

The motivation of workers is the primary responsibility of the supervisory staff and is a management function for the most part. But it is a function in which the industrial engineer can play a very important part. In this program would it not be well for the industrial engineer to look to his own relationships with management with the thought of perhaps strengthening that relationship in a positive manner. Staff people have too often looked upon themselves as specialists. In my company I am a staff man but I cannot duck my responsibility for the failure of my program to motivate people.

The discharge of the technical phases of your job is not the completion of your total responsibility. You, too, have a responsibility to the management of your company to collaborate with the workers of your organization to increase productivity and to raise the standards of work performance and improve the quality of your product. Technical recommendations to management as to methods of improving the job are not sufficient. An essential qualification of the industrial engineer of the future will be a person with highly developed human skills which fortify him in working successfully both with management and with workers to secure the maximum participation of both in the realization of the company's objectives.

As I see it, your major objective is productivity. The reason you are paid by your company is to improve present productivity, to bring about conditions that make it possible, and to work toward the attainment of constantly improving performance. With this basic goal in mind, your immediate and ultimate objective is not to please people nor to make them happy or satisfied, but to get them to produce. Getting people to produce is the essential part of management's responsibility but it is your responsibility to lay the groundwork, to set the stage, so as to make this production possible.

NOTES

THE ECONOMICS OF INVESTING IN MONEY-SAVING IMPROVEMENTS

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I consider it a real privilege to have been invited to address this group. Undoubtedly, you are here because you expect to take some additional knowledge home with you. I earnestly hope that we can fulfill this expectation and give you something which will be beneficial both to you and your company.

Our subject, "The Economics of Investing in Money-Saving Improvements"--or more specifically, "When Does It Pay to Substitute Capital Investments for Labor Payroll?"--is closely related to our professional activities. As a matter of fact, it holds the key to our lifeline in Industrial Engineering.

Preliminary Investigation:

At the time this assignment was accepted, I expected that the subject could be covered like any other routine job which would require some organizing for presentation. But as my analysis of various source material progressed, it was quite apparent that I was in the middle of a highly controversial matter. I was often reminded of the psychotic who thinks two and two is five and is highly elated over this discovery, in contrast to the neurotic who knows that two and two is four but is extremely unhappy over this result. As time went on, my sympathy switched from one to the other.

Industry has largely ignored the existence of advanced theories for measuring the economics of an investment. Frequently management has tried to avoid the deficiencies of the time-honored "rules of thumb" by expansion to include more factors, which usually results in more inconsistencies and misconceptions. The general lack of uniformity could indicate that no existing system is convincing or practical enough to become popular with industry. This condition exists in spite of some excellent theories advanced by outstanding professional men like Grant, Dean, Terborgh, Thuesen, Hill, Gregory, and many more names you would spot immediately as top-notch authors.

Of course, the difference in viewpoint between the Accountant and the Industrial Engineer has not contributed to the improvement of the situation because each pursues a different objective. The Accountant by nature is a historian, while the Industrial Engineer tends more towards being a prospector.

Each system has some inherent shortcomings. Some are difficult to apply or to understand, others will not give a correct or a complete answer to a particular economy problem, and others will not automatically weigh all the factors in a relative light. Of course, I realize that it is always easier to theorize than to make theories practical.

Current Practices:

To give you a general crosscut of the situation at large, may I quote from a survey conducted by Keachie, Gonzales, and Broum:[1]

> . . . . "Most firms contacted seemed to have some acquaintance with the theory of engineering investments, including the use of the time value of money and interest rates. But it was more honored in the breach than in the observance--"Too complicated.", "Not justified in our business.", "No time." However, all such excuses are plausible, and fortunately or not, any one of them may be true at a given moment. There was substantial evidence that many of the persons who conducted the economy studies were unfamiliar with both the concept of discounting a future sum of money to find its present value and with the considerations usually associated with the cost of capital. In fact, the cost of capital was usually assumed to be the same as the current yield on government savings bonds or bank saving deposits. In no case was there any indication that the cost of capital would be largely dependent on the means chosen by top management to obtain this capital."

This same survey also revealed that each company contacted used one system or another and that there was a wide spread in investment policies. The rate of return varied from sixty per cent to twenty-five per cent, and the payout period, from one year to five years.

It would be useless to speculate on the results which have been obtained in the past with so-called quasi-scientific management tools. We all may have a skeleton in the closet we would like to forget. I am not talking about projects which after a careful economy study have turned sour due to changing conditions. I am talking about projects which received preference over more lucrative ones or those which should not have been proposed at all.

This will apply especially to those cases where intangible elements have been introduced as bait or added incentive. Such intangibles are quality fears, company's reputation for elegance, effect on employee relations, good will, etc. It is evident that where funds are limited, approval of this type of weak investment would make otherwise sound investments impossible.

Need for Improved Tools:

Where in the evolution from manual to semi-automatic plants the ratio of labor savings to investment was very favorable, the evolution from semi-automatic to fully automatic plants promises a much higher investment in relation to labor savings.

1 -- E. C. Keachie, F. M. Gonzales, R. J. Broum, "Plant Investment & Survey Results", "THE JOURNAL OF INDUSTRIAL ENGINEERING", Vol. V, No. 3, May 1954.

Automation may not just mean new equipment and building changes, but entirely new plants. Processing might be affected even more than manufacturing. Recently I saw revolutionary designs of processing plants in Europe. The conventional batch system was replaced by the continuous flow system and centrally located automatic devices measured materials and controlled the process. This new era, which is just around the corner, will make extremely high demands on capital; consequently, a higher degree of accuracy is required to evaluate future investment opportunities. I will prove in the course of my talk that the ancient "rule of thumb" methods can no longer fill that bill.

One thing is apparent and that is the fact that we will be faced with many new problems in the future. While the pioneers of automation may claim technological success, they had to concede more often than not that the early ventures were economic failures. It is premature to generalize because the total impact of this evolution can not be measured for many years to come. Product or process changes may become exceedingly difficult and costly. This could require a staggering amount of new capital to be added during the life of a plant. In some cases, it could even lead to early abandonment of partly amortized plants. Even the present semi-automatic stage of industry has been an eye-opener to many of us and could be very indicative of what we can expect in the future. In recent years, labor reductions have failed in some cases to offset the higher fixed charges inherent in new plants as compared to older low cost or depreciated plants. Engineering could contribute a great deal to this unhealthy situation by finding, through intensified research, the answer to lower construction and installation costs, more flexible use of equipment by designing for rapid interchangeability, etc.

Mentioning these factors may seem today irrelevant to the subject at hand but as we approach the "New Look" in industry we may find the high ratio of investment to labor savings will not satisfy the present day bench mark for payout period or rate of return.

Requirements of a Sound Evaluation System:

Basically we are after two solutions. First, How profitable is a proposed investment? Second, What constitutes a satisfactory yield on an investment for a given company?

Naturally even the activation of qualified projects may be postponed if the company's cash position or contracted indebtedness makes it mandatory. When investment funds are thus limited, only those projects which actually pay for themselves within one year's time are assured of preferential treatment.

Without question, some authors and their disciples--they usually worked in groups--have found a scientific approach for determining a true measuring stick which would be indicative of the return on an individual investment. However, they have failed to provide a practical gauge which would permit judging the individual results obtained from an economy study by the general profit pattern of the given company

Various theories are offered to explain the principles involved in determining the cost of money or the applicable interest rate. A common approach for establishing the cost of capital for an individual company is seriously lacking; however, it is vital as a key for determining if it pays to invest funds in a particular project or not.

I shall propound the complicated theories advanced somewhat later in my paper, but I want to tell you now that no completely satisfactory answers can be expected from any of them.

An important factor in any scientific approach for improving the guideposts or decisions on capital expenditures is that it must be at least easily understandable by all concerned. This is essential because larger projects will have to pass through top management and the Board of Directors for final approval. Our top businessmen have little faith in theories which are not cut and dried. Therefore, it is extremely difficult to attempt to sell them complex formulas of unknown depth and origin.

PART I

PRESENT DAY SYSTEMS FOR MEASURING INVESTMENT PROFITABILITY

Let's turn now to five basic methods generally used by industry to measure the profitability of an investment. No purpose would be served to cover all variations of the basic methods. To simplify matters, I shall omit the tax angle in all calculations. The most common methods in use are the "Payoff", also frequently referred to as the "Payout Period", and the "Rate of Return" methods. These so-called "rule of thumb" methods suggest that they lack flexibility, technical background, accuracy, and reliability but otherwise their application is very easy. It is the over-simplification which made these methods popular with industry; consequently, their roots are deeply embedded in our business system and they will be difficult to eliminate.

1. Payout Method

The "Payout Method" is crude and superficial but the farmer is able to understand it as readily as the Chairman of the Board. The project cost is divided by the net savings to obtain the number of years required to pay back the initial investment. Proper deductions from gross savings are property taxes, insurance, maintenance, utilities, etc., but not depreciation or interest charges.

Example:

Cost of Project	$40,000
Yearly Net Savings	$10,000
Life of Equipment - 10 years (This item is not used in the calculations.)	

Answer:

$\frac{40,000}{10,000}$ = 4 years to pay back this investment.

Because this method ignores the time factor, the "Payout Period" of four years would not change whether the same investment had a life of ten or twenty years. Going one step further, one could assume that the ten-year life investment would return $10,000 annually for six years for a total of $60,000. The twenty-year life investment would return $10,000 annually for sixteen years for a total of $160,000. This reasoning is correct except any inference that the twenty-year investment would be 2.67 times better than the ten-year investment is false. Actually, as I shall prove later, the twenty-year investment is only 13.6% better than the ten-year one.

Interpretation of the "Payout Period" can lead to many fallacies because it fails to reflect the effect on return of those factors which change between projects and companies.

2. Rate of Return Method

The "Rate of Return" method, also simplicity itself, is even more dangerous. Because of its general inadequacies, numerous improved versions are in circulation and deciphering all of them would be a fruitless task. I shall confine myself to the unadulterated method which started the confusion. Here, the net profits (gross profits minus disbursements which include average depreciation) are divided by the original investment to indicate an annual return. If depreciation charges were left out, and this is also frequently done, the "Rate of Return" method would be the reciprocal of the "Payout" method.

Example:

Cost of Project	$40,000
Yearly Net Savings ($10,000 - $4,000 depreciation)	$ 6,000
Life of Equipment	10 years

Answer:

$$\text{Return on Investment} = \frac{\$6,000}{\$40,000} = 15\%$$

OR

on a 20 year life basis,

$$\text{Return on Investment} = \frac{\$8,000}{\$40,000} = 20\%$$

Terborgh[2] rightfully states that the calculations should be based on the average investment instead of the original investment. This change almost doubles the return as follows:

$$\text{Return on Investment} = \frac{\$\ 6,000}{\$22,000} = 27\%$$

2 — Terborgh, George, Dynamic Equipment Policy, New York: McGraw-Hill, 1949., Ch. 13, P. 204.

Terborgh[3] observes that if this method is used for evaluating equipment replacements, it holds the umbrella over old equipment far beyond its useful economic life. " All that is necessary to get a higher return is to wait a little longer."

Others quarrel about the way depreciation is treated. The popular straight-line method understates the rate of return and therefore application of the sinking fund method is advocated as being proper for the case.

However, there seems to be a general agreement among the authorities that it would be best for all concerned to abandon this method entirely.

3. Average Book Method

A third and a more serious doctrine is the "Average Book" method. Accountants would be more familiar with it than Engineers because it follows the accounting principles very closely. It relates the average profit to the average fixed assets remaining on the books. Both averages are taken over the life of the project.

Example:

Investment	$40,000
Average Investment	$20,000
Yearly Net Income ($10,000 - $4,000 depreciation)	$ 6,000
Life	10 years

Answer:

$$\text{Return on Capital} = \frac{\$\ 6{,}000}{\$20{,}000} = 30\%$$

This method is quite sensitive but does not always reflect a true relation under a given condition. For instance: If 50% of the invested capital, that is, $20,000 were to be expensed, the economic yield on the same example would be 60% thus making the proposition appear twice as attractive for no valid reason whatsoever. The actual tax advantage of $10,000 now as compared with ten yearly receipts of $1,000 each is percentage-wise considerably less than stated by the Book Method.

The rate of depreciation would also have an effect on the rate of return. In the example, the 30% return would be increased to 50% if accelerated depreciation were substituted for straightline depreciation. (This assumes income taxes remain the same during the life of the project.) This is completely erroneous since the only advantage accruing from the accelerated depreciation would be in deferring payment of a portion of income taxes to a later date.

In addition, the Book Method will show no change whether the yearly revenue from an investment is declining, increasing, or constant.

3 — Terborgh, op. cit., p. 206

4. "MAPI" Formula

The fourth method is one developed by Terborgh, Research Director of the Machinery and Allied Products Institute, and is called the "MAPI" Formula[4]. It is designed primarily as a guide for equipment replacement but the author also advocates its use for evaluating expansion projects and new equipment. Without doubt, Terborgh has given years of study to this specific field. Notable concerns like Allis-Chalmers and American Locomotive assisted in the initial testing phase of his formula.

In essence, the "MAPI" Formula provides a cost comparison between the old and proposed equipment for determining the economic propriety of replacement.

No other theory on this subject has been so well prepared. A total of three books explain the underlying philosophy and the practical applications[5]. The "MAPI" Formula is difficult to fathom and requires more knowledge than the mechanical application of the formula seems to call for. The adverse minimum continuously referred to by Terborgh[6] is the point which "is the lowest combined time-adjusted average of capital cost and operating inferiority obtainable from the machine." In other words, it is the ideal point where the combined capital and operating costs are the lowest for a machine. It is assumed for calculating purposes that obsolescence takes place at a uniform rate called the inferiority gradient. Terborgh also takes the stand that equipment actually never wears out, maintenance can restore it indefinitely. Just judging by the age of the taxis in Spain, which are all twenty or more years old, Terborgh's theory on the life of equipment could be defended for the most part.

Example:

Investment	$40,000
Salvage Value	0
Estimated Primary Service Life	10 years
Next Year's Variance in Operating Cost	$10,000
* Total Next Year's Cost for Proposed Equipment (from chart): 22% of $40,000	$ 8,800
First Year's Gain or Loss	+ $ 1,200

* Includes a 6% Interest Rate.

The end result of an economy analysis is expressed as the first year's gain or loss which is nothing more than a "go" or "no go" gauge.

4 — Terborgh, op. cit.
Machinery & Allied Products Institute, MAPI Replacement Manual, Chicago: Lakeside Press.
William Kelley & Co., Company Procedural Manual on Equipment Analysis, Chicago: Lakeside Press.
5 — Ibid
6 — Terborgh, op, cit.

The "MAPI" Formula deserves serious consideration for Engineers dealing with equipment replacement but for our purpose it is deficient because it does not show the expected rate of return on a proposed investment, nor does it readily indicate the profit ranking of projects. The more automatic we can make the priority selection of proposed investments, the better management decisions will be.

5. Investor 's Method

This brings me to the fifth and last version, the "Diminishing Capital Investment Method", also called the "Investor's Method." There is really little published data describing the method except that of Horace G. Hill[7] of the Atlantic Refining Company who has reduced the principles to writing. Another source of information is John C. Gregory,[8] who was Hill's co-author and who developed special interest tables and rules for application. John M. Schultz, also of Atlantic Refining Company, gave a paper on this subject at the AMA Special Conference on Capital Equipment Replacement held at New York in May of 1954.[9] Schultz explained the mechanics of the system as follows:

> "The Investor's Method of computing the rate on capital projects indicates the maximum rate of interest at which funds may be borrowed to finance a plan without causing it to show an ultimate loss. In other words, it determines the maximum discount rate which can be applied to all future net receipts so as to make their sum equal to the initial expenditure."

The Investor's Method is, in my opinion, the soundest approach in computing a rate of return on a proposed capital expenditure because:

1. It reflects, in a relative and absolute way, the time value of money which is controlled by mathematical laws.
2. Its accuracy and consistency is unmatched by any other methods provided the calculations take the effect of income taxes into consideration.

3. It is flexible and applicable to various types of projects requiring a capital outlay.

My reasons for expounding at length on the principles of "Payout", "Rate of Return", "Book Method", and "MAPI" Formula were purely psychological. Unless the facts presented are convincing in that the traditional methods give limited and at times erroneous answers, you would be hesitant to adopt a radical departure with the enthusiasm and interest it deserves.

7 -- Hill, Horace G., Jr., Rate of Return on Capital Expenditures, Berwyn, Pa., Aug., 1953.
8 -- Gregory, J. C., Interest Tables for Determining Rate of Return, The Atlantic Refining Co., Philadelphia, Pa., 1946.
9 -- Schultz, John M., "Tested Procedures for Handling Capital Projects," Capital Equipment Replacement, American Mgmt. Assoc., Special Report No. 1., 1954, pp 34 - 43.

The Investor's Method is basically concerned with only three elements of an investment transaction:

1. Cash outgoing.
2. Cash incoming.
3. Time value for both outgoing and incoming cash.

The math involved is nothing more than present worth calculations. However, the present worth theory is an unnatural way for most people to look at the value of money; therefore, I would like to recall some of the fundamentals.

Interest has been defined by Grant[10] as the time value of money. Because of the existence of interest, a dollar now is worth more than the prospect of a dollar at some future date.

Example:

Using the Compound Method, a dollar invested now at ten per cent interest will be worth $2.59 in ten years.

Using the Discount Method, one dollar due in ten years has a present worth of $0.38 at ten per cent interest. (See Figure 1.)

Table 1 graphically illustrates the principles of compounding and discounting.

All this may seem elementary but unless you clearly understand these principles, the Investor's Method will be no more than a mechanical tool with a mysterious foundation.

For better comprehension of the behind-the-scene action, it is advisable to explain four basic plans of repaying a ten year loan of $10,000 at six per cent interest. These plans, as illustrated by Table 1, are taken from Grant's textbook which, by the way, I recommend very highly for everyone to read. The payment plans and total costs are as follows:

Plan I The principal will be paid back after ten years as a lump sum.
Interest will be paid annually on the full principal.
Total cost of loan is $16,000.

Plan II Ten per cent of the principal will be paid off yearly.
Interest will be paid annually on the reduced balance.
Total cost of loan is $13,300.

Plan IV One single payment of principal and accumulated interest will be made after ten years.
Total cost of loan is $17,908.

10 -- Grant, Eugene L., Principles of Engineering Economy, 3rd Edition, New York: Ronald Press Co., 1950.

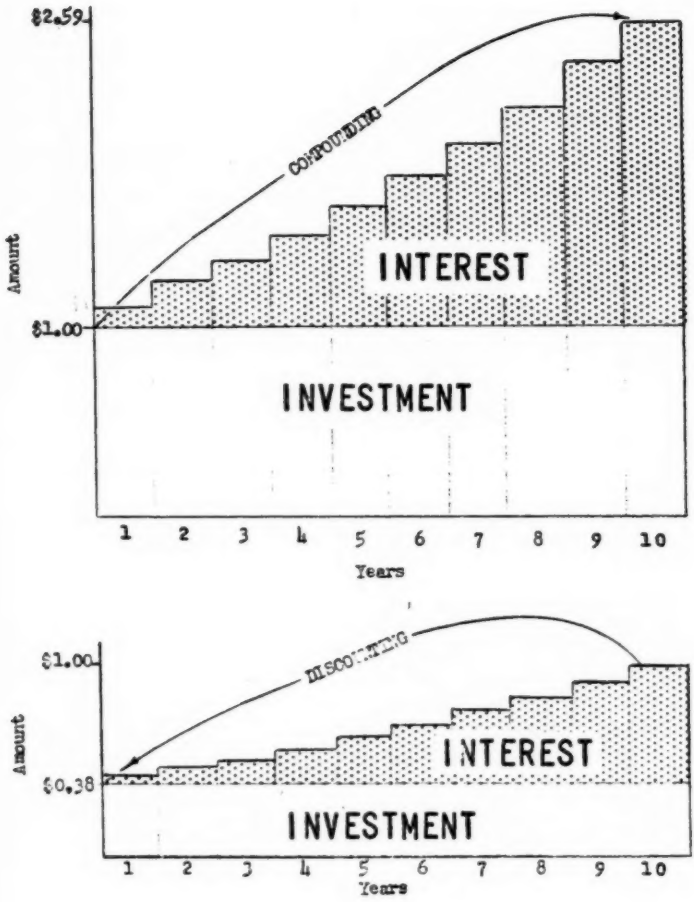

Fig. 1. Illustrating the principle of compounding and discounting money for 10 years at 10% interest.

Table 1. - Four plans for repayment of $10,000 in 10 years with interest at 6%.[11]

Plan	End of Year	Interest Due (6% of money owed at start of year)	Total Money Owed Before Year-End Payment	Year-End Payment	Money Owed After Year-End Payment
	0				$10,000
	1	$600	$10,600	$ 600	10,000
	2	600	10,600	600	10,000
	3	600	10,600	600	10,000
	4	600	10,600	600	10,000
I	5	600	10,600	600	10,000
	6	600	10,600	600	10,000
	7	600	10,600	600	10,000
	8	600	10,600	600	10,000
	9	600	10,600	600	10,000
	10	600	10,600	10,600	0
	0				$10,000
	1	$600	$10,600	$1,600	9,000
	2	540	9,540	1,540	8,000
	3	480	8,480	1,480	7,000
	4	420	7,420	1,420	6,000
II	5	360	6,360	1,360	5,000
	6	300	5,300	1,300	4,000
	7	240	4,240	1,240	3,000
	8	180	3,180	1,180	2,000
	9	120	2,120	1,120	1,000
	10	60	1,060	1,060	0
	0				$10,000.00
	1	$600.00	$10,600.00	$1,358.68	9,241.32
	2	554.48	9,795.80	1,358.68	8,437.12
	3	506.23	8,943.35	1,358.68	7,584.67
	4	455.08	8,039.75	1,358.68	6,681.07
III	5	400.86	7,081.93	1,358.68	5,723.25
	6	343.40	6,066.65	1,358.68	4,707.98
	7	282.48	4,990.45	1,358.68	3,631.77
	8	217.91	3,849.68	1,358.68	2,491.00
	9	149.46	2,640.46	1,358.68	1,281.78
	10	76.90	1,358.68	1,358.68	0.00
	0				$10,000.00
	1	$ 600.00	$10,600.00	$ 0.00	10,600.00
	2	636.00	11,236.00	0.00	11,236.00
	3	674.16	11,910.16	0.00	11,910.16
	4	714.61	12,624.77	0.00	12,624.77
IV	5	757.49	13,382.26	0.00	13,382.26
	6	802.94	14,185.20	0.00	14,185.20
	7	851.11	15,036.31	0.00	15,036.31
	8	902.18	15,938.49	0.00	15,938.49
	9	956.31	16,894.80	0.00	16,894.80
	10	1,013.69	17,908.49	17,908.49	0.00

11 — Grant, op. cit., p. 36.

Plan III A yearly payment is worked out with the aid of the applicable capital recovery factor (.13587) which makes the sum of the principal repayment and the interest payment uniform.
Total cost of loan is $13,587.

The latter scheme of financing is generally used by banks for home loans. There also is an analogy between Plan III and the Investor's Method for project evaluation where the revenue is obtained by uniform yearly payments.

For example, assume an investment of $10,000 to return annually $1,358.70 for ten years. Table 2 illustrates how principal and interest would be paid if present worth factors are applied to future income. In practice this could be a ten year home loan, or an investment in equipment with a ten year life. The amounts shown as principal recovery are synonomous with present worth of a future income and must total the amount of the original investment. The difference between these amounts and the total annual repayment represents the return on the investment.

Now let us further examine, clarify, and evaluate the present worth concept of the Investor's Method. If we compare Plan III of Table 1 with our example in Table 2, we note that the final results are similar. An annual payment of $1,358.70 will repay a debt or investment of $10,000 in ten years at 6% interest. However, during the ten year life of the two illustrations, the amount of principal or interest to be repaid each year is in reverse order of time. This difference in order of repayment is due to the different objectives of the illustrations.

The Investor's Method assumes the position of a lender who is interested in the present worth of a future sum. The conventional repayment plan assumes the viewpoint of a borrower who pays interest on the diminishing balance. Figures 2 and 3 graphically illustrate these concepts.

The calculations for the aforementioned examples were executed with conventional interest tables. However, specially developed interest tables by J. Gregory[12] are more detailed and designed to facilitate determination of rate of return for equipment investments. Where the timing of the original outlay of cash precedes any revenue by some time period, the compounding portion of the tables is used. If the annual return is uniform, the tables permit present worth calculations of five year periods. It also provides tables designed for declining revenue, and receipts occurring instantaneously at the end of each year or continuously during the year. Table 3 is a reproduction of one page of these tables.[13]

12 -- Gregory, op. cit.
13 -- Ibid.

Table 2. - Illustrating how $10,000 principal plus interest would be paid if present worth factors are applied to future income at 6% rate over a ten year period.

Years	Income	×	Present Worth Factor @ 6%	=	Principal Recovery	Interest (Income minus Principal Recovery)
0-1	$1,358.70		.9434		$ 1281.7	$ 77.00
1-2	"		.8900		1209.1	149.60
2-3	"		.8396		1140.7	218.00
3-4	"		.7921		1076.2	282.50
4-5	"		.7473		1015.4	343.30
5-6	"		.7050		957.9	400.80
6-7	"		.6651		903.7	455.00
7-8	"		.6274		852.4	506.30
8-9	"		.5919		804.2	554.50
9-10	"		.5584		758.7	600.00
	$13,587.00				$ 10,000*	$ 3,587.00

*Please note that the sum of the principal recovery must equal the initial investment. This is proof that the correct present worth factor was applied. Close differences as established by two trials of different present worth factors may be interpolated when attempting to determine the rate of return on a proposed investment.

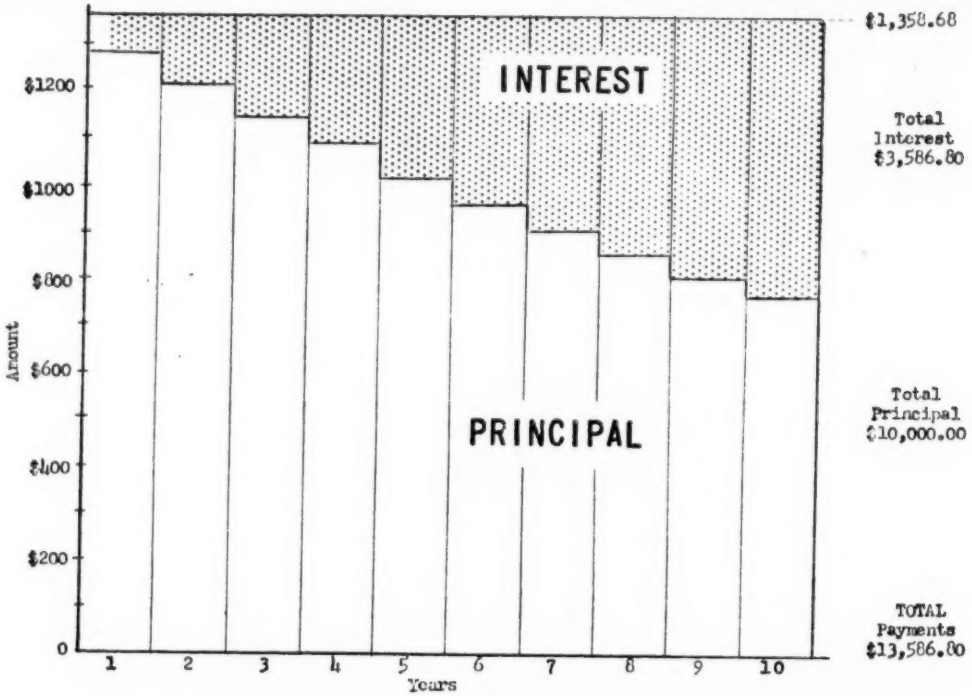

Fig. 2. Present worth concept of the plan to repay $10,000 in 10 years at 6% interest.

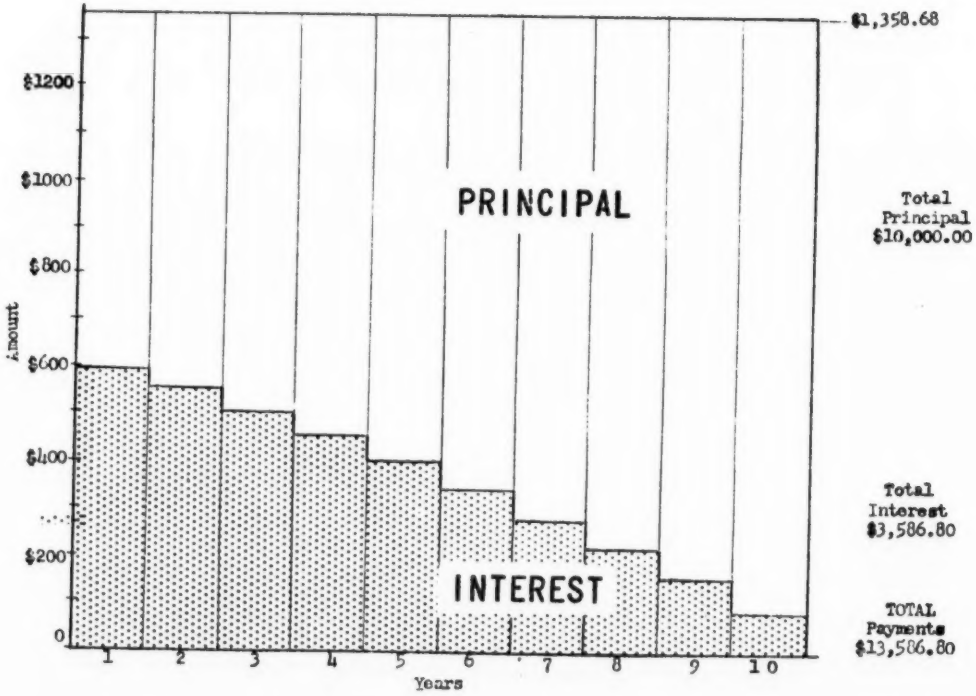

Fig. 3. Illustrating plan to repay $10,000 in 10 years at 6% with interest being paid on the diminishing balance.

Table 3. - Reproduction of a portion of interest tables for determining rate of return.[14]

CONTINUOUS INTEREST TABLE

COMPOUNDING PERFORMANCE BEFORE REFERENCE POINT WHICH OCCURS:	11%	12%	13%	14%	15%	16%	17%
A. IN AN INSTANT							
1 MONTH BEFORE	1.0092	1.0101	1.0109	1.0117	1.0126	1.0134	1.0143
2 MONTHS "	1.0185	1.0202	1.0219	1.0236	1.0253	1.0270	1.0287
3 " "	1.0279	1.0305	1.0330	1.0356	1.0382	1.0408	1.0434
6 MONTHS BEFORE	1.0565	1.0618	1.0672	1.0725	1.0779	1.0833	1.0887
9 " "	1.0860	1.0942	1.1024	1.1107	1.1191	1.1275	1.1360
12 " "	1.1163	1.1275	1.1388	1.1503	1.1618	1.1735	1.1853
B. UNIFORMLY UNTIL REFERENCE POINT							
FROM 3 MONTHS BEFORE TO 0	1.0139	1.0152	1.0164	1.0177	1.0190	1.0203	1.0216
" 6 " " " 0	1.0280	1.0306	1.0332	1.0358	1.0385	1.0411	1.0437
" 9 " " " 0	1.0424	1.0463	1.0504	1.0544	1.0584	1.0624	1.0666
" 12 " " " 0	1.0571	1.0625	1.0679	1.0734	1.0789	1.0844	1.0900
FROM 2 YEARS BEFORE TO 0	1.1185	1.1302	1.1420	1.1540	1.1662	1.1785	1.1910
" 3 " " " 0	1.1848	1.2007	1.2230	1.2428	1.2629	1.2835	1.3045
DISCOUNTING PERFORMANCE AFTER REFERENCE POINT WHICH OCCURS:							
C. IN AN INSTANT							
1 YEAR LATER	.8958	.8869	.8781	.8694	.8607	.8521	.8437
2 YEARS "	.8025	.7866	.7711	.7558	.7408	.7261	.7118
3 " "	.7189	.6977	.6771	.6570	.6376	.6188	.6005
4 " "	.6440	.6188	.5945	.5712	.5488	.5273	.5066
5 " "	.5770	.5488	.5220	.4966	.4724	.4493	.4274
10 YEARS LATER	.3329	.3012	.2725	.2466	.2231	.2019	.1827
15 " "	.1921	.1653	.1423	.1225	.1054	.0907	.0781
20 " "	.1108	.0907	.0743	.0608	.0498	.0408	.0334
25 " "	.0639	.0498	.0388	.0302	.0235	.0183	.0143
30 " "	.0368	.0273	.0202	.0150	.0111	.0082	.0061
D. UNIFORMLY OVER INDIVIDUAL YEARS							
FROM 0 TO 1 YEAR	.9470	.9423	.9377	.9332	.9286	.9241	.9196
" 1 " 2 YEARS	.8483	.8358	.8234	.8112	.7993	.7875	.7759
" 2 " 3 "	.7800	.7613	.7230	.7053	.6879	.6710	.6546
" 3 " 4 "	.6808	.6574	.6349	.6131	.5921	.5718	.5522
" 4 " 5 "	.6099	.5831	.5575	.5330	.5096	.4873	.4659
FROM 5 TO 6 YEARS	.5463	.5172	.4895	.4634	.4386	.4152	.3931
" 6 " 7 "	.4894	.4588	.4299	.4029	.3775	.3538	.3316
" 7 " 8 "	.4385	.4069	.3775	.3502	.3250	.3015	.2798
" 8 " 9 "	.3928	.3609	.3314	.3045	.2797	.2569	.2360
" 9 " 10 "	.3519	.3201	.2910	.2647	.2407	.2189	.1991
E. UNIFORMLY OVER 5 YEAR PERIODS							
FROM 0 TO 5 YEARS	.7892	.7520	.7353	.7192	.7035	.6883	.6736
" 5 " 10 "	.4438	.4127	.3839	.3571	.3323	.3093	.2879
" 10 " 15 "	.2560	.2265	.2004	.1773	.1570	.1390	.1231
" 15 " 20 "	.1477	.1243	.1048	.0881	.0742	.0624	.0526
" 20 " 25 "	.0852	.0682	.0548	.0437	.0350	.0281	.0225
F. DECLINING TO NOTHING AT CONSTANT RATE							
FROM 0 TO 5 YEARS	.8393	.8267	.8144	.8024	.7906	.7792	.7679
" 0 TO 10 "	.7155	.6961	.6776	.6598	.6428	.6265	.6109
" 0 TO 15 "	.6186	.5958	.5745	.5544	.5355	.5178	.5008
" 0 TO 20 "	.5417	.5176	.4953	.4747	.4555	.4376	.4210
" 0 TO 25 "	.4797	.4555	.4334	.4131	.3948	.3775	.3614
FROM 0 TO 30 YEARS	.4292	.4055	.3840	.3645	.3468	.3306	.3157
" 0 " 35 "	.3874	.3645	.3440	.3254	.3088	.2936	.2798

14 — Gregory, op. cit.

If we use the same basic example we have used to analyze the previous systems, we find the following:

Example:

Investment	$40,000
Life	10 years
Yearly Net Income	$10,000

Answer:

Rate of Return = 22.32%

OR

If the life is 20 years:

Rate of Return = 25%

Table 4 shows the calculations involved using the Investor's Method and Gregory's continuous interest tables.

This, in concentrated form, is the Investor's Method and here is what it does in its original form as outlined by its author, Mr. Horace G. Hill, Jr.[15]

1. Varying Policy of Capitalization:

The Investor's Method does not take into consideration whether the investment is partly capitalized or expensed. The cash outlay is the same in either case except for a slight tax deferment advantage on the expensed portion.

2. Varying Policy of Amortization:

The Investor's Method does not recognize different depreciation methods. It is assumed that a project could not be made more valuable by applying a different amortization policy except for income tax considerations.

3. Varying Patterns of Cash Receipts:

The Investor's Method recognizes the speed at which the cash outlay would be recovered. It will show a higher rate of return on the project with the shortest payout period and vice versa. For instance, on a project of the same investment, life and income, the rate of return would be twenty-two per cent if yearly revenue is uniform. The rate would be thirty-six per cent if receipts are on a declining scale and 15% if receipts are on an increasing scale.

4. Varying Salvage Value:

The Investor's Method will reflect future receipts from salvage even though it might be small when discounted at a high interest rate during the life span of the project. (Table 5 shows the effect of a salvage value on our basic example.)

15 -- Hill, op, cit.

Table 4. - Calculation of rate of return using Investor's Method.

Investment $40,000
Annual net income . . $10,000

With a 10-year life:

Years	Income	Present Worth Factor @ 22%	Principal Recovery	Interest (Income minus Principal Recovery)
0- 5	$10,000 x 5	.6065	$30,325	$19,675
5-10	10,000 x 5	.2019	10,095	39,905
Total	$100,000		$40,420	$59,580
			Approx. $40,000	Approx. $60,000

Rate of return: Approx. 22% (exactly 22.32%).

With a 20-year life:

Years	Income	Present Worth Factor @ 25%	Principal Recovery	Interest (Income minus Principal Recovery)
0- 5	$10,000 x 5	.5708	$28,540	$ 21,460
5-10	10,000 x 5	.1635	8,175	41,825
10-15	10,000 x 5	.0469	2,345	47,655
15-20	10,000 x 5	.0134	670	49,330
Total	$200,000		$39,730	$160,270
			Approx. $40,000	Approx. $160,000

Rate of return: Approx. 25%.

Table 5. - Illustrating the effect of salvage value on rate of return (Investor's Method).

Invest $40,000 at start of operations.
Life of equipment = 10 years.
Savings = $10,000 per year uniformly received.
Salvage value = $10,000.

Years After Zero Point	Amount Received	Interest Table	R^1 = 25% Factors	R^1 = 25% Value at Zero Point	R = 23% Factors	R = 23% Value at Zero Point
0	-$40,000		0	-$40,000	0	-$40,000
1	10,000					
2	10,000					
3	10,000	E	.5708	28,540	.5942	29,710
4	10,000					
5	10,000					
6	10,000					
7	10,000					
8	10,000	E	.1635	8,175	.1882	9,410
9	10,000					
10	10,000					
Salvage	10,000	C	.0821	821	.1003	1,003
				V^1 = (-$ 2,464)		V = (+$ 123)

Interpolation

$$\text{Rate of return} = R + \frac{V(R^1 - R)}{V - V^1} = 23 + \frac{123 \times 2}{123 + 2,464} = 23 + \frac{246}{2,587} =$$

$$23 + 0.1 = \underline{23.1\%}.$$

5. Pre-operating Investment:

The Investor's Method does not confine itself to the period of operation but considers all cash transactions as equally pertinent; consequently, a project that pays off immediately after acquisition has a real advantage and a higher rate of return than one which carries idle investment for any appreciable period. (Table 6 shows the effect of investment one year prior to initial revenue.)

Tables 5 and 6 illustrate the method of determining a rate of return by selection of trial rates from a published table. The required accuracy is controlled by interpolation.

The authors of the Investor's Method adopted the philosophy that by omitting income tax complications in the beginning, it would simplify the calculations until all fundamental principles had been settled. They were of the opinion that the rate of return on the great majority of projects would not show an appreciable difference if evaluated before tax and adjusted according to the tax rate for after tax income or if computed after including tax as one of the basic annual expenses.

I have checked the effect of income taxes on three basic issues:

1. In halving the rate of return before taxes, assuming a tax structure of fifty per cent, the result would be slightly understated. For instance: our basic example has a rate of return of 22.32% or halved at 11.16% but a separate calculation, which includes income taxes, changes the rate of return to 12.6%. (See Table 7.)

2. Expensing part of the investment for present tax advantage has considerable effect on the rate of return. For instance: if fifty per cent (or $20,000) of the basic project were capitalized and fifty per cent expensed, the rate of return would be twenty-eight per cent instead of twenty-two per cent for one-hundred per cent capitalization. (See Table 8.)

3. The tax effect from straightline depreciation versus accelerated depreciation (sum of the digit method) is significantly different. For instance: if accelerated depreciation is used in our basic example, the rate of return after income taxes would be fourteen per cent. (See Table 9.)

A plant which uses only straightline depreciation could allow for understating the rate of return after taxes by lowering the company's minimum requirements for proposed projects accordingly.

Summary:

In summarizing my investigation for the one best method to determine the profitability of an investment, I have come to the conclusion that -

1. The Payout Method is useful only as a rapid over-all check but no more.
2. The Conventional Rate of Return is treacherous and should not be used at all.
3. The Average Book Method fails to portray all variables in a relative light.

Table 6. - Illustrating the effect of early investment on rate of return (Investor's Method).

Invest $40,000 one year before start of operations.
Life of equipment = 10 years.
Savings = $10,000 per year uniformly received.
Salvage value = 0.

Years After Zero Point	Amount Received	Interest Table	R^1 = 18% Factors	R^1 = 18% Value at Zero Point	R = 16% Factors	R = 16% Value at Zero Point
-1	-$40,000	A	1.1972	-$47,888	1.1735	-$46,940
0						
1	+ 10,000					
2	10,000					
3	10,000	E	.6594	32,970	.6883	34,415
4	10,000					
5	10,000					
6	10,000					
7	10,000					
8	10,000	E	.2681	13,405	.3093	15,465
9	10,000					
10	10,000					
Net receipt	$60,000			V^1 = (-$ 1,513)		V = (+$ 2,940)

Interpolation

$$\text{Rate of return} = R + \frac{V\,(R^1 - R)}{V - V^1} = 16 + \frac{2{,}940 \times 2}{4{,}453} = 16 + \frac{5{,}880}{4{,}453} =$$

$$16 + 1.32 = \underline{17.32\%}.$$

Table 7. - Illustrating the effect of deducting income tax before and after calculating the rate of return.

Investment . . . $40,000
Life . . . . . 10 years
Annual income . . $10,000

Before taxes:

Years	Income	22% Factor		Value at Zero Point	Taxable Income
0- 5	5 x $10,000	.6065	=	$30,325	$20,000
5-10	5 x 10,000	.2019	=	10,095	40,000
Total	$100,000			$40,420	$60,000
50% Federal Tax					30,000
Net income					$30,000

Rate of return before taxes = 22.32%.
Divide by two for after taxes = 11.16%.

After taxes:*

Years	Income	12% Factor	Value at Zero Point
0- 5	5 x $7,000	.7520	$26,320
5-10	5 x 7,000	.4127	14,445
Total	$70,000		$40,765

Rate of return after taxes = 12.6%.

* -- Taxes = $\frac{\text{Yearly income - Depreciation}}{2}$

Net income = Income - Taxes

Table 8. - Illustrating the effect of expensing a portion of the initial investment.

Total Investment	$40,000
Amount Expensed	$20,000
Life	10 years
Annual Income	$10,000

Years	Income	28% Factor	Value at Zero Point
0-5	5 x 9,000	.5381	$24,214
5-10	5 x 9,000	.1327	5,972
	90,000		$ 30,186

Rate of Return Before Taxes = 28%

NOTE: The tax advantage is that $10,000 of the $20,000 is expensed immediately instead of $1,000 annually for ten years. In the calculation above, the net initial cash outlay is $30,000 ($40,000 less $10,000 Tax Rebate).

Table 9. - Illustrating the effect of income tax when using an accelerated depreciation.

Investment $40,000
Life . . . . . 10 years
Annual Income $10,000

Year	Income	Depreciation	Taxable Income	Taxes	Income After Taxes	14% Factor	Value at Zero Point
1	$ 10,000	$ 7,272	$ 2,728	$ 1,364	$ 8,636	.9332	$ 8,059
2		6,545	3,455	1,727	8,273	.8112	6,711
3		5,818	4,182	2,091	7,909	.7053	5,578
4		5,090	4,910	2,455	7,545	.6131	4,625
5		4,363	5,637	2,819	7,181	.5330	3,827
6		3,636	6,364	3,182	6,818	.4634	3,159
7		2,909	7,091	3,546	6,454	.4029	2,600
8		2,181	7,819	3,910	6,090	.3502	2,132
9		1,454	8,546	4,273	5,727	.3045	1,744
10		727	9,273	4,636	5,364	.2647	1,419
Total	100,000	40,000	60,000	30,000	70,000		39,854

Rate of Return After Taxes = 14%.

Summary: (cont'd)

4. The MAPI Formula is a systematic and intelligent approach for equipment replacement but too limited for industrial engineering and management use.
5. The Investor's Method makes use of scientific principles. It reacts to every cash transaction and also measures the time value of money. These factors highlight the outstanding qualities of the Investor's Method and would best satisfy industry's requirements.

The fine pioneering work done by Hill, Gregory, and Schultz, of the Atlantic Refining Company, Philadelphia, Pennsylvania, brought us much closer to a practical and flexible method, and should contribute to better investment decisions.

PART II

DETERMINATION OF A STANDARD RATE OF RETURN

Having established how to calculate the profitability of an investment, we come to the second part of my subject: "What is a fair return on an investment for a given company?" This question is about as broad and academic as defining, "What is a successful businessman?" Each one of us has some definite ideas about that subject, especially since we like to think that we belong to this group. The field is wide open and the situation gets more confused as intangible values are thrown in to come to the aid of an arbitrary salary level. The best definition--I believe I read it in the Literary Digest--was a yearly salary of $25,000 plus a liberal spending account.

Cost of Capital or Fair Return Theories:

Going back to the fair return on an investment--this is the benchmark I have frequently referred to--let us look at some of the theories advanced. Earlier we mentioned that excellent work has been done to develop a system for determining the true rate of return on individual projects and also that there has been little progress in arriving at a practical gauge or benchmark for judging the excellence of such investments against a company standard. This is not intended as criticism, but rather to emphasize the need for much more work and agreement on the principles of capital cost.

Now to our theories:

Schultz[16], an experienced disciple of the Investor's Method, explains the rationale as follows:

> "In order to make investment decisions, a company must have a financial yardstick which will measure all investments on a common basis."

16 -- Schultz, John M., "Tested Procedures for Handling Capital Projects," Capital Equipment Replacement, 1954, Special Report No. 1, pp. 34-43.

"Assuming that the profit effects of replacements and additional equipment are properly appraised, they must both be measured against the cost of capital in order to make sound business decisions.

The cost of capital to the company is the sum of the various rates of interest which the company must pay or earn to satisfy all investors--short term, long term, and equity. This cost of capital may be expressed as a rate of return on the total company investment, and the individual projects therefore must be measured on a rate of return basis to determine whether or not they meet the minimum requirements. If the rate of return of the project, as measured by the Investor's Method, is higher than the cost of capital, the project is a desirable one. If the rate of return is less than the cost of capital, the project is undesirable."

Joel Dean, in Capital Budgeting,[17] writes the following:

"As a practical problem, estimating cost of capital has three elements--Finding market values, finding costs of flotation, and determining capital structure." . . . .

. . . . "In principle, the decision on where to cut off capital expenditures and when to supplement internal funds from external sources should be governed by current cost of capital. A serious drawback to this rule is the fact that the cost of capital fluctuates violently and that stockholders have long memories and slight comprehension of these matters."

My use of the term "Interest" in this report is synonomous with rate of return and has nothing to do with the cost of bank loans, unless so stated. Coming back to the survey by Keachie, Gonzales, and Brown,[18] I would like to quote their findings on interest rates:

"The Interest Rate: It would seem that since the interest rate is common to all economy studies, no matter what the particular approach, that there would be some agreement as to the method of obtaining the interest rate best suited for practical application. However, this is not the case; there seem as many approaches as there are authors. In view of the significance of the interest rate used in economy studies and the importance of these studies in general it was deemed that further investigation of the interest rate was necessary."[19] . . .

17 — Dean, Joel, Capital Budgeting, New York, Columbia University Press, 1951, Ch. 13, p. 45.
18 -- E. C. Keachie, F. M. Gonzales, R. J. Brown, op. cit.
19 — Brown, Robert J., An Investigation of the Interest Rate in Engineering Economy Studies., Unpub., M. S. Thesis, Univ. of Calif., Sept., 1953.

. . . . Purpose: To facilitate the study of the interest rate, the following purposes were established: 1. to compare the two broadest concepts of an interest rate used for discounting future sums of money and the interest rate at which capital earns money; 2. to present the businessman's choice of an interest rate as revealed through investigative interviews; and 3. to find the common meeting-ground between theory and business practice in the selection of an interest rate for engineering economy studies."

Evaluation of Theories:

As I interpret Schultz's[20] findings, the cost of capital could be expressed by the following formula:

$$\frac{\text{Profit before tax + interest on debt}}{\text{Net worth plus debt}} = \text{Past return.}$$

Using the cost of capital as a measuring device implies that there must be a relationship between the past earnings on old assets and the future earnings of new assets. This, however, would not be true for all companies. It would be an impossible benchmark where past earnings were extremely low. It also could be a handicap to companies with a high profit level if it precludes otherwise sound investment opportunities.

While Dean[21] advocates that the factors influencing cost of capital should be determined individually, their effect on the rate of return should be reflected by this or a similar formula using net worth and earnings as a starting point.

Keachie, Gonzales, and Brown[22] suggest that the standard rate of return must be the combined result of theory and business practice. Their approach has merit because it advocates the evaluation of all business factors which may lead to the development of a realistic standard.

Practical Approach:

For better general understanding I want to make it clear that the standard rate of return is the minimum rate which will make a proposed investment attractive. It is intended that this benchmark serve as a burglar alarm. The rate should not be lowered but management may raise it whenever the financial conditions of a company warrant.

Since it is impossible to provide you with a uniform formula to fit all cases, I shall enumerate some of the practical aspects which give an indication as to the range for a standard rate of return.

20 -- Schultz, op. cit.
21 -- Dean, op. cit.
22 -- Keachie, Gonzales, Brown, op. cit.

The establishment of such a benchmark assumes that an investment bargain is equally attractive to any company regardless of its past earnings.

When individually developed, it is important to know that the standard must include not only earnings but also interest on borrowed capital. Contrary to accounting principles, Grant[23] advocates that internal funds be charged with interest in the economy study because these funds could earn interest when invested elsewhere. If dividends and interest on bonds were identical, the cost of financing through stocks is more than double the cost of borrowed capital because interest is tax deductible and dividends are not.

It should not be the function of Industrial Engineers to attempt to evaluate the various concepts of financing. This phase properly belongs to the financial division of a company.

Technically, any investment which earns more than its financing cost will add to a company's profits. The difference between a minimum profit and a satisfactory profit reflects the evaluation of risk involved in capital investment. Elements of risk arise from external rather than internal factors of a company. Outside influences--such as business recession, change in product design, changes in customer behavior, changes in federal laws, and technological improvements--are uncontrollable; therefore top management must accept risk as a business fact in long-range decisions. Equity capital must be protected by seeking a considerably higher return on new investments than the bare financing cost. Higher returns, of course, mean shorter payout periods and therefore reduced risk. This theory is borne out by actual industry practices. Current surveys indicate that two-thirds of industry insists on a rate of return between 33 and 50 per cent. Terborgh[24] on the other hand, is of the opinion that a minimum rate in excess of 30 per cent is overconservative.

Using the national average return on net worth of leading manufacturing concerns gives some indication of the earning power of assets. In 1953, net profits were 12½% of net assets which may correspond to a return of 25% to 30% before taxes.

A rule-of-thumb method frequently used by the layman for appraising a business is that the annual income before taxes should be 20 per cent of the total value. Relating this rule-of-thumb method to the national return on net assets seems to justify consideration of a range from 20 to 30 per cent.

23 -- Grant, op. cit.
24 -- Terborgh, op. cit.

Summary:

To summarize my analysis of the standard rate of return for a specific company, I find:

1. That the theory advanced by Schultz[25] is workable in companies where the past earning record is satisfactory in the judgment of management.

2. That where the past earning record is below 20%, it is an indication that earnings are substandard; consequently, management must establish a synthetic benchmark designed to improve their earning power.

3. That where the past earning record is above 30%, it may not be appropriate for use as a minimum rate of return. A benchmark set too high may preclude otherwise sound investment opportunities.

PART III

ECONOMY STUDY

So far we have covered the measurement of the profitability of an investment and the evaluation of this result against a company standard.

The economy study concerns itself with finding the net differences in total cost of alternatives. This phase must be an integrated part of the whole system because the time value of money also plays a role in selecting the superior alternative as measured by the rate of return. To this, I would like to offer a few observations from my own experience on some of the factors involved in the economy study.

The Investor's Method will bring out the time value of money in investments of different lives. An interesting fact is that equipment with a long life does not pay out well after twelve years. If we assume a standard return of 25% and disregard the differences in maintenance costs, the installation of a wood tank having an estimated life of four years and costing $4,000 is a much better buy than a stainless steel tank costing $15,000 and having an estimated life of twenty years. Using the respective capital recovery factors of .42344 and .25292, respectively, the wood tank would have an approximate $2,000 advantage per year. Even if the cost estimate for the wood tank is changed to $6,000 to allow a 20% price increase for each of the four subsequent replacements, the wood tank would cost $1,250 per year less than the stainless steel vessel.

25 -- Schultz, op. cit.

Some projects are lucrative enough to include related installations which are desirable from an operating point of view but which do not individually meet the standard rate of return. This practice leads to unnecessary expenditures. Therefore, it is important that each integrated part or phase of an economy study be examined as to its individual profitability and its relation to the standard return.

The next point, and a highly controversial one, is the treatment of sunk cost in an economy study. Sunk cost is the remaining book value of an investment which could not be recovered by depreciation charges when the projected life was shortened for economical reasons. While it is a cold fact that past expenditures are irrelevant to the yield of a new investment, the experience gained from past events should influence future predictions. Here is an example which illustrates the point: My company, Anheuser-Busch, operates 35 bottle and canning units valued at $500,000 to $750,000 each. Technological developments in our industry brought about continuous increases in machine speeds. The speed of can lines jumped from 200 to 600 cans per minute in less than 20 years. Future speeds of 800 or 1,000 cans per minute are possible. If we would, in the economy study, apply our usual depreciation rate of 12 years we could justify new equipment every four to six years, thereby creating a very dubious state of economy. The life of the economically obsolete equipment should be reflected in the estimated life of the new equipment, thereby curbing senseless spending.

One item frequently overlooked in the preparation of operating estimates is the proper allowance for maintenance of the new asset. A check into maintenance charges of all plant equipment may indicate a much higher percentage than is usually allocated to the new asset.

A practical method we frequently employ is the back-door approach for projects which are a business necessity but must operate within certain economic limits such as warehouses, delivery depots, etc. The project cost is developed from the overhead that a particular operation can economically bear and the facilities are planned to fall within that range.

Finally, a sound policy for carrying out the savings projected by an economy study is most important. Projects processed by the Industrial Engineering Department must be endorsed by all responsible parties. This also includes the foreman of the department affected by the change to make certain that there is complete agreement on the savings to be obtained. In this regard, detailed written operating procedures of the contemplated change are a necessity. Estimates should neither be loaded nor should they include questionable savings.

* * *

In closing, may I emphasize that investing in money-saving improvements requires more than just a good formula--it takes foresight, timing, judgment, and a sound program. Diversified, piecemeal improvements may pay off as calculated, but improvements which are part of a master plan will collectively yield a higher return. There is also danger in pursuing extreme policies. Overinvesting in labor saving equipment will push up the break even point. On the other hand, neglecting to modernize may impair the competitive position of an enterprise.

NOTES

Apr. 7, 1955.

TIMESTUDY TO-DAY

A.I.I.E. St. Louis
May 12, 1955
Ralph Presgrave

Since our discussion is likely to be somewhat rambling and speculative, I must make some attempt to circumscribe it, not so much for the purpose of precise delimitation as in the hope of gaining a little perspective. But first a definition. "Timestudy" for present purposes will include the optimization of method (if there is such a word) along with the setting of a time-standard. "Work-study" would be a better term.

Any one who takes his timestudy seriously is keenly aware that any appraisal must look farther than the technicalities involved. Indeed, I would consider it an affront to this audience to use up all our time assessing inventions and systems, for I find it hard to believe that you are not better informed than I am about such things. One has only to skim through a few copies of the A.I.I.E. Journal to reach this conclusion.

The matters of technique and application, essential as they may be, do not exist in a vacuum and they cannot be fully considered apart from the social, the economic, even the moral, atmospheres in which they must operate. It is a far cry from, say, the technical intricacies of a bi-manual digital motion chart to the even more intricate social problems either created or solved, by our evolving industrial practices. And yet there is a close linkage throughout and at no point can we draw the line and say that beyond this point timestudy is not concerned. This is because timestudy is not an end in itself but merely one of the means to an end. That end is the fruition of an economic philosophy so profound that it is yet barely understood, and one that carries social implications that cannot yet be appraised.

Thus the precise future of technique cannot be assessed except in relation to innumerable influences, the interaction of which will always be obscure. Among such influences are the extension of automation; the uses to which our growing leisure is put; the maturing of trade unions; new inventions, especially those relating to electronics and to nuclear fission; evolving political doctrine; the exigencies of war (hot or cold); the rising proportion of older people; the conservation of natural resources; the problems of feeding an over-fecund world; the form of education; the extension of domination

by the state over areas once reserved to personal liberty. All these and more bear on the shape of timestudy as it serves the economic principle to which North American society above all others is committed. I hardly need to expound the principle which, as you all know, is based on the idea that the less time it takes to make something the more people can have it.

In spite of what I have said about technical matters, the force of the principle makes it perfectly valid to approach timestudy on a strictly technical basis. For timestudy must be amenable to scientific scrutiny quite apart from the circumstances in which it must operate or the uses to which it may be put. Obviously this approach is essential at times, in fact it is fundamental. On the other hand it may be as academic as timestudy itself is academic if not put to the test of practical use. Here I am thinking specifically of wage incentives. I do not discount the value of timestudy in matters of layout, cost-estimating, production planning and so on, for it is almost indispensable to these and their attendant controls. Nevertheless in such areas the social significance of timestudy diminishes and it becomes little more than a mathematical exercise. Errors may be gross before they are detected; inconsistency may never be discovered; standards can be changed arbitrarily and no one really cares. Timestudy is always under wraps until it is used for incentive purposes, when it provides the control data for what a man is required to do and how much he shall be paid for doing it.

These are vital and touchy matters and will always have a strong influence on the progress of timestudy. Nevertheless we must guard against viewing timestudy as a mere formula for arriving at task times or piece-rates. Certainly it has been expedient for its detractors to so regard it. Not without instances of justification, they have seen it solely as a means of systematically exploiting the worker. The more percipient have seen that had this really been the case it is doubtful if timestudy could have survived. The truth is that much of the strength of timestudy lies in the fact that it is the vitalizing factor in a system designed to permit the worker to exploit his own aptitudes and capacities for his own advantage.

If this sounds a bit too high-minded I would be the first to agree that this purpose has not always been easy to detect and the system has not always been so well intended. Let us then look for a moment at this system which seems to betray the ill-intentions of both its detractors and its promoters, if only by surviving.

The system is merely the intelligent elaboration of the rough stages of Hiring, Learning and Paying ("learn" here being a transitive verb). By Hiring I mean the careful selection of the individual by interview, tests and what not, leading to placement

in the work for which he is best suited by his physical and temperamental attributes. By "Learning" I really mean training by sound methods, which also implies the use of motion analysis so highly detailed that job-standardization and job-specification permit training with close precision. "Paying" involves the intelligent design of the wage incentive plan and its equitable administration so that the man can cash in on his abilities and training without being affected financially by incidental vagaries over which he has no control.

To reduce such a scheme to practicality we must have quantitative numbers. Timestudy provides those numbers. It is the key to the system.

All this smacks more of the idealistic than it does of the objective stocktaking which our title suggests. This stock-taking must have an eye to the future for timestudy can hardly be said to have arrived. The main purpose of assessing its present status is to provide a surveyed point which, lined up with previous points, should help in plotting the direction and foreshadowing the destination.

To say that timestudy has not arrived does not deny that there have been advances in technique and even greater advances in acceptance. To a great extent circumstances conspired in this. Economies forced by the depression, followed by the demands of war gave timestudy a tremendous impetus. As a result its extension over the past decade has been marked, not only in North America, but in all the world's industrial countries. Most members of management would now regard it as much a part of business life as is accounting. Labour unions, once violently opposed, now range from tolerance to full acceptance. Universities and technical colleges, once chary, now take pride in their schools of Industrial Engineering.

All this is as much an indication of the economic essentiality of timestudy as it is of its ability to rise to the responsibilities which that essentiality entails. We shall return to this later, but for the moment may I digress to shed a sidelight on the claim that timestudy has not quite arrived.

The actual term timestudy is not self-explanatory. While some might regard it as technical jargon, it is now such a commonplace in industry that it should really be in the public domain. It is encountered in industrial conversation at all levels, it is above all familiar to millions of industrial workers. In most newspapers, advertisements for timestudy men appear frequently. It is safe to say that there are thousands of words in the dictionary

that are definable by fewer people than those who could define timestudy, and yet I know of no dictionary that lists the word. Many newer words appear, in spite of the fact that here is an important term that is following the orthodox passage from the two-word stage (with capitals) through the hyphenated period, and is now frequently spelled as a single word (lower case). Perhaps when it reaches the standard dictionaries in the latter form it will have arrived.

Well, to get back to our prophesying, if one can call it that, we have already indicated the two main areas to be explored. The first and most obvious is that of technical advance. The other is that of acceptability. By the latter I do not mean the political attitudes of unions, or the likes and dislikes of the workers. These are all serious factors, but what I am really thinking of is the degree of compatibility of the aims and philosophies of timestudy with our industrial, social and economic mores.

I suppose what this really means is that we must consider timestudy in terms of people - individually, in certain groups, or as a nation. For survey purposes we may well start with an individual - F. W. Taylor. Discounting the aura of omniscience that his disciples have promoted and admitting that he may have made errors, a re-reading of his work reveals that here is an excellent bench-mark, in fact probably the only precise one from which to start a survey. After half a century his "Principles of Scientific Management" is barely dated in its technical aspects and not at all in its theories.

The proposals he made as to the techniques of work study are now bearing fruit. The principles he expressed are more widely understood and accepted than ever before. If Taylor was on the right track, then we are still on the right track, for we have not deviated in any appreciable sense. This may raise the suggestion that here is a profession of faith rather than a statement of reason, that we are merely being loyal to the patron saint. Actually I believe the true and impelling factor is inevitability rather than faith or rationalization. By this I mean that timestudy is so completely in the spirit of the times and so typical of the socio-economic policy to which this country is irretrievably committed that it, or its equivalent, is indispensable. No equivalent has yet appeared. No critic, amiably disposed or not, has been able to do more than snipe at details, more with the purpose of improving than of finding a substitute. As a system of measurement it is in tune with the engineering age. As a major element in the reduction and control of costs it could not be more timely.

This puts timestudy into direct relationship with the general public whose members, whether they approve, disapprove or are unaware, are willing to accept its consequences. All those who

accept the theory that productivity is the basis of our economy, indeed all who accept the fruits of that principle accept timestudy whether they believe so or not. If in all seriousness they do not accept, then they must also refuse the products of invention and discovery for they are cut from the same piece.

This does not mean that all timestudy need be accepted. Nor does it mean that the future of timestudy will be a glorious procession without halts or detours. It is certain that progress will be hampered, as in the past, by opposition, as well as by incompetence and abuse. In this respect we must consider two (or maybe four) groups, i.e. the Trade Unions and those for whom they act and the Industrial Engineers and those for whom they act.

We can assume that most mill workers will continue to dislike timestudy to some extent, while vaguely recognising the need for it, and on the whole preferring it to discriminatory rates set by the foreman or even by bargaining. There will continue to be complaints about timestudy in general and about certain standards in particular - but, as now, there will also be complaints about tardiness in studying jobs.

It is fairly safe to say then, that timestudy will become steadily more tolerable to the rank and file because of improved techniques, improved communication and greater familiarity. While some may regret it, it seems likely that the mere existence of Unions will tend to re-assure the individual. I am thinking of the protection offered by the Unions rather than of their official attitude toward timestudy. This varies from union to union, and even in the one union there are wide variations from local to local regardless of a fairly rigid policy at top level. This latter disparity arises because the Unions by their function and structure are political bodies. This is not necessarily undesirable, but it does mean that their actions and attitudes are largely governed by expediency.

While expediency is rarely predictable, certain trends have developed which are not likely to be reversed, first because of public statements made by officials of the Unions and second because economic pressures usually prevail over short term opportunism. The trends are indicated by a change in emphasis. Once timestudy was opposed as such. Now it is usually accepted but the methods, accuracy, consistency and so on are questioned. Some of the large internationals employ timestudy experts and we may expect them to hire more and more technical advisors to assist them in bargaining, in grievance procedure and in badgering management. A few years ago I would have been naive enough to prophesy a rapid growth in joint Union-Management timestudy departments. Now I am doubtful of either the likelihood or the desirability in any foreseeable industrial structure. Technical

collaboration is not quite the function of a political body. There will of course be some exceptions where a special relationship has developed on the basis of personalities. Even so there are those who feel that the Unions can contribute more as gad-flies than as yoke-fellows.

I have been talking as if timestudy were a matter of economic inevitability come what may. Obviously this is not so. Technical competence and integrity must be sustained or economics will be just as inexorable in the opposite direction. This means that the future of timestudy is in the hands of another group - the timestudy men themselves. Not only are they the trustees for technical development, but also they hold the key to most of the human aspects. Will the timestudy man be equal to the demands that he must face? I can answer that question with much greater assurance than I would have dared, say, ten years ago, for it has been a matter of genuine gratification to me to witness the solid improvement in the calibre of the work-study practitioner in recent times. Some of you will remember the days when management, observing the startling achievements of a few consultants, assumed the whole thing was pie. As a result, any clerk who could readily be spared was given a text-book, a stop-watch, a slide rule, a sub-marginal salary and a blessing. Even those who approached the matter seriously could get very little instruction and in the main had to teach themselves. It is to their credit that they taught themselves well. They formed the nucleus of the current crop. From my personal observation it is an excellent crop indeed and will provide the seed for an even better crop in the future. Industry has learned to demand men of high standards of education and special training and I have no hesitation in stating that industry very often gets better than it deserves or realises.

This too is changing as more and more industrialists are coming to understand the importance of work-study and the associated techniques. I have mentioned the part the universities are taking. I must also refer to the sincere efforts that are being made towards professionalisation, the growth of serious-minded societies such as the A.I.I.E., the growth of a substantial technical, critical and philosophical literature.

I must not conclude without some reference to technical developments in timestudy. However, it should be borne in mind that the general pattern seems to be established and that innovations are mainly in the nature of refinements. A notable instance is the encouraging development of Predetermined Motion Times. While they represent the Standard Data carried to its logical conclusion, they do not represent the ultimate in refinement, for any motion, simple as it may appear, is actually a complex that defies analysis. However, further refinement may well be considered to come under the head of basic research aimed more at fuller understanding than at the compounding of detail. The present compromise with the ultimate seems

to be eminently sound.

Of course there are flaws and inconsistencies and limitations, and these have quite properly been the subject of criticism. However, I cannot help but feel that a good deal of the criticism seems under compulsion to find something wrong and that in any case many of the objections, while technically valid, deal with matters that fall within the limits of experimental error and practical tolerances. On the whole I have no doubt as to the essential feasibility and rationality of the Predetermined Time systems. I base this as much on consideration of the principle as on observation of the results under controlled conditions. I sincerely believe that, given reasonably objective reception, they will improve to form the basis of the work-study of the future.

While their validity has been questioned, no one has disputed their incomparable value in method study. Because of this they should be of great assistance in alleviating the timestudy man's number one headache - the so-called creeping change. Eventually also they ought to eliminate the perennial disputes about Rating. This is because Rating is a makeshift forced on us in default of an adequate statistical picture of element times. Predetermined Motion Standards supply that lack by their very nature.

Mention of statistics raises a ghost - one that I believe can never be laid, but which, in one form or another, will always haunt timestudy throughout technique and throughout application. I refer to the fact mentioned by the occasional observer, but apparently not generally understood, that timestudy is founded on and devised about statistical concepts and yet must be applied to the individual. Virtually every factor in timestudy - element times, fatigue factors, delay allowances, interference formulas and what not - when reduced to numbers become statistical values of one type or another, and must then be directed at individuals who may or may not conform to the norm which the figures represent.

In the last analysis most of the problems of timestudy and of incentive plan application come from the area of individual non-conformity. Because the dilemma is rooted in human deviation from the psychological and physiological mean it is inherent and insoluble. And here it is an unfortunate anomaly that improvement in the precision and consistency of standard setting will do little to improve the basic situation. For instance, predetermination of motion times will not lay the ghost. The times themselves are statistical concepts of a highly specific nature and the refinement of detail in which they deal and the rigidity of the motion pattern which they lay down, may well intensify the problem. At the same time they bring it into sharper focus and give the observer some assurance in dealing with it.

The problem will not be handled by technical devices but rather by dealing sympathetically and intelligently with the individual - by selection, by training, by guidance. In other words the solution is by avoidance rather than by cure.

Vaguely recognising the situation, some will make the perfectly obvious and acceptable statement that human values outweigh all others. From this they argue that technical integrity is a secondary consideration and that as a consequence work standards should be adjusted, if not established, by bargaining.

I do not need to discuss the fallacy of this or to point out that it would in no way solve the basic problem so long as some specification of task and award is necessary! Nor do I need to point out the dangers of compromising technique because of maudlin or threatening pressures.

May I conclude by pointing out that the Industrial Engineer is a unique type of Engineer in that he has the opportunity and, I trust, the capacity to reconcile the strictly scientific approach of true engineering, with warm comprehension of the human aspects of the revolutionary developments in which he is involved.

This opportunity obviously entails grave responsibilities. I have every confidence that these responsibilities will be met and that as a consequence the future of timestudy will be bright and fruitful whatever shape that future may take.

NOTES

ELECTRONICS IN WORK MEASUREMENT

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The standard of living of the American citizen has made many significant increases in the past fifteen to twenty years. Many branches of our economy and many fields of endeavors can righteously take a great deal of credit for assisting in this increase. Certainly, we Industrial Engineers feel quite proud of our record. However, we would be remiss in our relationships with many branches of industry and science if we did not recognize how completely related and interlocking are the branches and arms of technology in achieving this result.

None of us can disagree on the fact that much of our progress to date has been due to the advent of more electronic devices. Our modern day home conveniences attest to this development to the layman as well as to the technician. The television set, the outdoor-indoor temperature controls, even the radio are factors in our standard of living which are due in major part to electronics. We are even more familiar with electronic devices in our industries. The automatic computers, recording devices, inspection and quality devices are likewise but a minute part of the total electronics picture in industry and business. Even then, electronics holds a much brighter future for us than it has already given to us. A recent series of articles in the newspapers have highlighted some of the probable devices available to mankind within the next fifty years. Although these devices themselves are enough to jolt the imagination of anyone, past experience has proven that even this rosy picture will fall far short of reality when the fifty years are past.

It was just a matter of time until electronics became introduced into the work measurement picture. Electronic devices have been used repeatedly for making measurements of all sorts more accurate than ever before, like inches, pounds, etc. There can be no question that work measurement needs more accurate answers than it has been able to supply in the past. It was only natural to follow up the need for greater accuracy with an attempt to apply electronic principles in the search for answers.

It should be noted that the attempt to reach for greater accuracy in work measurement is not an academic one. Literally billions of dollars rest on foundations which consist in some major portion of work measurement values. This tremendous amount of money is not only related to utilization of invested capital, in equipment and materials, but also to the wages and purchasing power of millions of people. Both management and labor have a great stake in such a technique. Work measurement deals with and affects all types of people, Presidents and workers, supervisors and union stewards. In this sense, the technique of work measurement is dependent on the human beings involved, as well as on their technical usage and application. If there are any inaccuracies or inconsistencies in the strictly

technical sense, then there is a large area for the development of friction between the parties (usually management) applying and using the techniques, and the parties (usually workers and unions) to which the techniques are applied. Such friction is contrary to the present trend in labor-management relations, which is toward more and more cooperation. This cooperation can be expected as a natural result of the present human relations awareness on the part of management and, probably just as important, of the developments from technical research. More cooperation can be expected between parties of any nature when the base on which they operate is broader and has more common foundations. The errors in work measurement have caused many grievances, arbitration cases, and strikes, and these errors have come from a lack of accurate theories, information and measuring devices on which to base many of the decisions needed in a continuing program of labor-management cooperation.

On the other hand, management alone needs the basic information work measurement provides in order to be efficient. In many companies it would not be possible to balance efficiently work and production lines; determine equipment requirements, establish proper manpower requirements, plan production, plan costs of new products and revisions of old products, control production, and control the costs of production without some form of work measurement. Although some of these functions can be accomplished without work measurement, work measurement is the one tool which becomes fundamental for the proper functioning of all of these industrial and business needs. With this background it becomes more apparent that the area of work measurement is a natural for the application of electronics.

In our context it might be wise to indicate that work measurement consists of two basic techniques. One is time study, and the other is standard data. Standard data techniques consist of elemental standard data and basic motion standard data. Both types of standard data rely on preliminary measurements which, in one form or another, are based on time study. Because the fundamental techniques of time study directly affect the establishment and validity of standard data, much of the remainder of this paper will deal with time study; whatever benefits time study will also benefit standard data. In addition, some pertinent comments will be made later in direct relation to standard data.

Time study determines the amount of time an operation or element of operation, performed with a given method under given job conditions, should take when worked on by an operator, possessing the necessary skill, and given sufficient training to perform the operation properly, working at the pace, maintainable throughout the day, week, etc., specified as equivalent to the work necessary to earn base pay; and when all the operator's required activity and needs are provided for. Although this definition may appear lengthy, it is brief in relation to all of the possible factors which affect an operator's performance and, therefore, affect the time study procedure. A review of this definition points out that there are certain factors which affect the performance of an operator that are not measured, but must be maintained above, or within, certain levels. These factors are the given method, the skill of the operator (which is assumed to be at a certain minimum level) and training of the oper-

ator (this is likewise assumed to be at a certain minimum level). There are other factors operating within these conditions which have to be measured in the time study process. These factors are the conditions of work surrounding the operation (which means the operator's needs must be determined), the difficulty of the work itself, the actual time it takes the operator to perform a task, and the pace at which the operation is performed by the operator.

Most practitioners will recognize these four measurements as being necessary for time study. However, it is important that a relationship be found for these four factors, or the measurement of these factors by themselves would not help reach the goal of the time study definition. This relationship must be theoretically sound, as well as practical, in the sense of today's economy and management-labor relationships. For this reason, it is important to examine the relationship which is sought by means of the time study process so that it will be possible to better understand how and why electronics will help the time study, as well as the whole work measurement, procedure.

To establish this relationship it is necessary to understand the basic time-efficiency curve under which all industries and businesses operate today for wage payment purposes mainly.[1] In almost

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[1] For a complete and detailed discussion of the above points and the material below concerned with Figures 1, 2 and 3, see B. Nadler, Motion and Time Study, New York: McGraw-Hill, 1955, Ch. 20

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all cases the standard time for performing an operation is considered the 100% efficiency point. For example, if the allowed or standard time is one minute per unit, and the average production of the operator is 480 units per eight hour work day, then the operator is considered to be working at 100% efficiency. If the operator averages 960 pieces per day, or .50 minutes per unit, then he is considered as 200% efficient. Likewise, averaging two minutes per unit is considered as 50% efficient. This is shown graphically in Figure 1. Because this relationship is considered fair and proper and is used widely, the relationship of the measured variables in time study must follow the same pattern. To make it simpler to follow and understand, it is possible to convert the curve of Figure 1 to a 45° negative slope straight line, as shown in Figure 2 by plotting the variables of time and operator performance (efficiency) on a logarithmic scale. In effect, this straight line in Figure 2 represents the desired end result of the time study process.

The relationship of Figure 2 is the expression for the operation as a whole, an element of an operation, or even a basic motion like any one of the therbligs. However, discussion will be related to a usual element in time study. An element is defined as a group of homogenous therbligs performed together to accomplish one component of the work required in an operation. Although this unit is frequently recognized as a common base in time study, it should be reemphasized that the "whole operation" or a "basic motion" can be substituted in place of the word "element" in the following discussion.

The time and performance (pace rating) of an operator on an element are usually measured first. These two measurements locate a point on a logarithmic scale graph through which a 45 degree line of negative slope is passed. This line, number 1 in Fig. 3, is the basic assumption of time study, and it is based on the time-efficiency curve mentioned before. From this line it is possible to determine the time at standard pace for the element. Notice that if another operator were timed and rated on the element, as indicated by points C and D, that the same line would relate his two measurements for the same element. The next measurement of job difficulty is made, and its net result is to indicate that the pace level of the element under study is actually less than the standard pace without difficulty. By adding back this amount of pace reduced, line 2 is established and provides the base time for the operation. The allowance measurement adds time for the various purposes required, and this results in line 3. From this line, which is the basic assumption line shown in Figure 2, it is possible to determine the standard time for the element. Although graphs of this nature are not made in actual time study, this graph explains the process used when the ordinary calculations are made.

Time study is statistical in nature because when one operator (one set of conditions) is measured for the element under study, he produces a wide variation of time values for that element, as shown around Point A in Figure 3. (A physical relationship would produce a very narrow range of values when one set of conditions for a relationship is measured.) If it were possible today, this wide distribution would also be obtained for the ratings assigned to the operator performance each and every time the performance of the element was made. That is, as every time value is recorded for the element, a rating value should theoretically be made at the same time and it would provide a similar type distribution as shown around Point A, around Point B. Obviously, the problem now becomes one of finding the most accurate ways of making the four measurements required.

One of the most important requirements before any accurate measurements can be made is the necessity for a complete description of the conditions to be measured. Three important problems which face the time study practitioner in relation to methods description are (1) What is the exact method to be recorded (this refers to the exact therbligs;or finger motions involved in the performance) (2) How much detail will be necessary to make an adequate record of the method that has been decided upon, and (3) By what means will it be possible to detect a change in the method being used by an operator. Although many words have been recorded in the past few years about how accurately it is possible to make a methods description, the fact still remains that there are many ways of performing a specific element even within the realm of the most accurately devised methods description technique available today. We need more accuracy.

The timing measurements are usually considered to be the most accurate in time study work today. This is basically true even though there are many difficulties of obtaining accurate information with the stop watch and even with motion pictures. For example, a stop watch depends upon a human being observing a particular point in the performance of a series of motions. This observation in it-

self can be highly variable within the motion pattern in addition to the additional errors of reading a watch and reading the time. Motion pictures are frequently difficult to analyze and, in many cases, the opinion of the analyst observing the pictures plays an important role in the determination of the recorded time for a particular element. These points means that even more accuracy would be desirable for the timing process.

The measurement of operator performance, usually called rating, is generally acknowledged as being the most inaccurate and least reliable of the measurements in time study. In almost all cases, it is not even possible to perform the minimum theoretical requirement of making a pace measurement of an operator on an element each and every time that element is performed. Although recent years have seen the introduction of motion pictures as an aid to better rating, there are many problems yet to be solved. One of the fundamental contributions in recent years, however, has been the theory that the measurement of operator performance is best accomplished by measuring the speed of his motions. In addition, the "speed" component of the motion which seems to affect the performance is usually defined as the acceleration and deceleration of body members. Obviously, measuring these components of motions has not been done at all on any type of industrial operation.

The measurement of job difficulty is even more vague in many cases because most systems of rating attempt to take this measurement into consideration by human judgment of the difficulty of different jobs. Since difficulty of the job affects the pace or speed of the operator on the job, the same comments made about rating for pace comparison above apply to difficulty comparison. Although some experimentation has been performed in the area of job difficulty and these results have been used in practical situations, these results are no better than their basic measurements and assumptions.

The measurement of allowances pertains to many different items. For example, personal time is usually included in allowances; if an operator were not permitted to take personal time which is needed for physiological purposes he would not be able to perform his work as effectively. Obviously, the performance of work is related to the speed of motions. Likewise, other allowances include unavoidable delays and irregular occurrences. Although unavoidable delays are not usually associated with the speed of the motions, irregular occurrences are related to the same measurements of time, pace and difficulty as are regular elements of work. In the same way, machine time control allowances are related to the expected pace which an operator can perform when he has the opportunity to be idle during a certain percentage of the cycle time. In those systems that use a fatigue allowance, it is felt that the nature of the work would cause the operator to have a reduction in performance if there were no time for resting. Obviously, this is directly related to the speed of motion concept as well as to the job difficulty concept.

Almost every measurement technique in time study is related to the measurement of just what motions are performed, time, and speed, in terms of acceleration and deceleration of motions. The fundamental errors come from a lack of ability to fulfill the unique require-

ments of measuring human body motions, and whatever measurements are made require human judgment which is highly variable. There is a definite need for knowledge of motions and their performance applications, not only in the entire field of industrial engineering, but also in other phases of engineering as well.

The only existing measuring device is the motion picture camera through which an approximation of velocity and acceleration is obtained. There are many limitations to the motion picture procedure for obtaining velocity and acceleration.

1. The motion picture is basically a two-dimensional medium. It is extremely difficult, if not impossible, to align two cameras in the correct orientation to obtain the necessary components of velocity and acceleration with the desired accuracy of no more than plus or minus 1 to 2 percent deviation from the true values.

2. The problem of distortion arises when using any type of optical equipment. It is difficult to keep this distortion to a minimum in the laboratory, let alone in the industrial situation.

3. The method of obtaining velocity and acceleration information from the film does not lend itself to the required level of accuracy. The film must be projected and the motion pathplotted in order to obtain a distance vs. time curve which is differentiated to obtain velocity. Also, there is the problem of differentiating this curve another time to obtain acceleration and deceleration. A small error in any of the earlier stages of this measurement procedure would be greatly magnified in the later steps.

Another, and most important problem, is the present inability of motion pictures to measure the velocity and acceleration of small motions occuring at the end of the movements from place to place. Some of these small, or terminal, motions are assemble, position, grasp and select. A measuring instrument had to be developed to solve this problem. By exploring the possibility of applying electronics to this problem, a possible suitable solution has been obtained.

It should be emphasized at this point that work on applying electronics to work measurement and time study problems has been performed by other people. However, all of the work that has come to the attention of the author pertains to the measurement of time only, and does not make any attempt to measure the other factors in time study. However, the net effect of relieving a time study man of the work of timing is to give him more time for concentration on the performance of the operator which, in turn, permits him to apply his judgment procedure of rating more conscientiously. This, however, does not necessarily improve the ratings. Two other research projects should be reported.

(1) Professor Rowe, in California, has developed a device which measures accurately to one millionth of a second. The problem with this device is that it needs microswitches and other devices attached to, and in, the work surface to obtain the time values. It gives no record of what happens between contacts with a microswitch or crossing a photo electric cell.

(2) A device, called the Metarfac, developed by Mr. Ewing, of R. R. Donnelley & Sons Company, in conjunction with International Business Machines Company representatives, is basically a data processing piece of equipment operating from holes in a tape placed in the tape by punches operated by the time study analyst. This device times only what is recorded by the analyst. Therefore, its accuracy is no greater than the usual paper tape machine. The main advantage of the Metarfac is that it completely eliminates the work of the time study man in compiling the data from the time study information and it prints the final answers desired on a piece of paper. Again, there is no attempt to measure performance of an operator electronically.

A device used to study motions would have to operate under all conditions of factory and equipment location, surrounding equipment, and operators. Any attachment to the body member, if needed, should be so small and so light that it will not interfere with the motion being studied. Another requirement is that the apparatus would have to give a three dimensional summation of velocity and acceleration since a body member is potentially able to move in any direction or plane. The lower velocity limit should be zero with the upper velocity design limit about ten feet per second. However, the acceleration and deceleration components may well range from zero to 320 feet per second squared. The apparatus should give information about distance and direction of motion and velocity vectors, as well as magnitude of velocity and acceleration. This problem has been worked on at the Washington University Motion and Time Study Laboratory most diligently by Jay Goldman for his doctoral dissertation in Industrial Engineering.

The solution to this problem seems to have been found by applying the well-known scientific principle, the Doppler effect. This principle states that if a source and recipient of cyclic phenomena (like sound waves, electromagnetic waves, etc.) are in motion relative to each other or, more apparently, one is stationary and the other in motion, the recipient will receive a varying cycle frequency based on the speed of the motion between the two. For example, a slow speed of motion toward the stationary recipient will slightly increase (above the emitted source) the cycle frequency received; a fast speed toward the stationary recipient will increase the received frequency very much; a slow speed away from the recipient will slightly decrease the received frequency, etc. Many types of source of cycle phenomena were investigated in the attempt to arrive at the most suitable media. Some of these possibilities were radar, sonar, and radioactive electromagnetic waves. From all the possibilities, sound waves were selected as the most logical because they seemed to present less formidable obstacles than any of the other possibilities.

The emitted frequency of sound is above the sonic level so as not to interfere with general operator performance, and to reduce possible noise interference with the device from operating equipment and machines in plants. The basic operating procedure of the universal operator performance analyzer and recorder, or UNOPAR as the device is called, starts with the inaudible sound source (in this case, 20,000 cycles per second) attached to the body member being studied. Most of the limited research work performed to date assumes that the wrist will be used as the major body member to be studied; however, ramifications of the equipment will eventually make the device suit-

able for hands, fingers, and other body members. The sound source is connected by light wires to the oscillator, which produces the required frequency signal. If more than one body member is involved in an operation, different frequency signals could be used to differentiate the different members involved. To better explain the entire process, Figure 4 shows the block diagram of the UNOPAR.

In addition to the 20 kilocycle oscillator, a 21 kilocycle oscillator is used to provide a reference signal. The 20 k.c. and the 21 k.c. are mixed to obtain one k.c. which is used as a calibration of the system. The 20 k.c. source is then amplified and emitted through the speaker attached to the body member. The emitted sound waves are picked up by three microphones oriented in three planes perpendicular to each other so that each microphone picks up a vector of frequency change in the direction perpendicular to the source. The three microphones are each ten feet away from the center of a cubic yard within which it is assumed the work will be performed. The distance of ten feet is used to keep to a minimum the error involved in moving the sound source away from the theoretical center of the cube. The maximum error thatcan be incurred with the sound source at the greatest distance away from the center of the cube is 1%. For almost all activities, the error will be much less than 1%.

The block diagram shows only one microphone and its circuit since the same circuitry would be used for the other two microphones. After the signal has been picked up by the microphone, it is amplified and mixed with the 21 k.c. source to determine the instantaneous number of cycles received. For example, if the speaker source is stationary, then the mixer produces a result of 1 k.c. If the speaker source was moving away from the microphone, then the result of the mixer would be less than one k.c. If the speaker source was moving toward the speaker, then the result from the mixer would be more than one k.c. The resultant frequency is then amplified and converted into a D.C. voltage which is the basic requirement for recording. This voltage can then be plotted and is proportional to the velocity of the motion. Because there are three such channels of circuits, three velocity plots can be obtained at this point to indicate the velocity of the body member in the three planes. The electronic implementation of all these stages has been checked and calibrated to show that there is a direct proportional relationship between incoming differences of frequency at the mixer to the outgoing voltage at the conversion to voltage

As each of the three velocity components are obtained, they are then differentiated electronically to obtain the acceleration and deceleration of the member in each of the three planes. In effect, at this stage, there are six different plots vs. time (three velocity, three acceleration) which are used mainly in motion study work and in methods description work in time study, as described below. Each of the three velocity components is then squared electronically, and the three squared velocity components are electronically added. The square root is taken electronically, and the result is the total velocity of the body member during motion. In the same way, each of the three acceleration components are squared, then added together and a square root taken to provide a resultant acceleration plot for the motion as a whole. A typical section of plots for the total

velocity and acceleration for two motions is shown in Figure 5.

Also included in the present design of the UNCPAR is a stage to provide information concerning the position of the hand at any given instant and the distance the hand actually moves. This is accomplished by integrating electronically each velocity component to obtain a distance vs. time plot for each of the three planes. Likewise, each individual distance component can be squared, the three squared values added, and the square root taken to provide a resultant distance vs. time plot for the motion as a whole. Also, the individual plots of distance vs. time for each plane provide an exact picture of the location or position of the body member involved at every instant of time.

Even if there were no other benefits of the UNCPAR, one of the most readily apparent results is that exact information about each and every motion of each element of each cycle is recorded, whereas all other procedures of motion and time study obtain only overall information. Obviously, this is a basic requirement for any good measurement procedure.

The UNCPAR has been checked to determine if it measures correctly the velocity and acceleration of a motion. The test motion was established in one plane by having the hand move a tube, to which the speaker was attached by means of a frame, over a rod for a distance of about 30 inches. A plus or minus 2g (1g = 32.2 feet per second squared) accelerometer, with an accuracy of 1% (full scale), was used as the source to provide information for the criterion acceleration-time plot directly and through electronic integration the criterion velocity time plot. (The accelerometer can not be used as a measuring device like UNCPAR because the accelerometer makes measurements in one plane only. Conversely this is the reason that the UNCPAR can only be checked by means of a one plane motion; there would be no criterion source for a two or three dimensional motion which would be accurate enough for the purpose. Originally it was planned to use motion pictures of a one plane motion and a two plane motion for criterion purposes. However, one of our preliminary tests with 64 frames per second motion picture provided a much too gross record of information. The reason for this was discussed above in relation to possible measurements of acceleration and velocity.)

Each microphone and its accompanying electronic equipment for converting frequency difference to voltage were tested individually by placing the microphone directly in line with the motion. Although it has not been done at the time of writing of this paper, a two-dimensional test will be conducted by offset placing of two microphones (90 degrees between microphones) in the horizontal plane with the rod. In the same manner, a three-dimensional test will be made by offset placing of three microphones (90 degrees betwen microphones) in direct relationship to the motion. In the one plane test of the device, the UNCPAR velocity plot was checked with the criterion velocity plot by means of chi-square and correlation. The chi-square probabilities were almost completely above .97 and .98, and correlation gave similarly high results indicating a very close agreement between the criterion and UNCPAR plots. Additional statistical checks were made by calculating the standard deviation of the percent differ-

ences in maximum velocities plotted on the UNOPAR record and on the criterion record. Also the standard deviation was calculated for the difference between the time for the motion from the UNOPAR record and the criterion record. The results of these calculations showed that the standard deviation for the maximum velocities was 3.4%, and for the time for the motions was 6.7%. Although these standard deviations are not satisfactory enough for our basic objective, it was possible to tell from the velocity plots just what was causing the errors in the UNOPAR plotting. At the time of writing (February-March) corrections were being made and new results will be available at the time of the conference. It is anticipated from preliminary tests made after the corrections were started that the standard deviation for maximum velocities will be cut more than half and the standard deviations for time will be cut more than four times. It seems, therefore, that the UNOPAR can be assumed to measure accurately the actual velocity and acceleration of body motions. (At any rate, the measurement of velocity and acceleration with the UNOPAR at present accuracy levels is so much more accurate than any existing procedure or technique that the UNOPAR can be considered for practical purposes to be an accurate measure even though some errors still exist.)

It should be noted here that one of the basic assumptions underlying the conclusion that the UNOPAR can measure accurately is that since it measures a one plane motion accurately, it will also measure a three plane motion accurately. Although it is not necessarily desirable to make such an assumption, there is absolutely no way of getting a criterion measurement of velocity and acceleration for a three plane motion which involves less error than the UNOPAR itself. Because of this lack of criterion measurement for three plane motions, the assumption mentioned above is not only tenable, but is also practical.

Although acceleration and velocity of the total motion for every motion is obtained with the UNOPAR, the device is not ready for industrial application for time study or work measurement purposes because much more work must be done to be able to interpret properly the measurements made. The problems in this respect are many fold: Should each motion be considered a separate element? Are individual motions truly separable? How should acceleration and/or velocities be combined or related to obtain "average" for regular element? How are the records to be interpreted to use acceleration for combination motions? Are acceleration and deceleration correct indicators of operator performance? Fortunately, the UNOPAR itself will help solve these problems, because if acceleration and deceleration are not the correct measures of operator performance (which was a basic hypothesis leading to the development of the device) the UNOPAR will be of great help in deciding what the measure of performance should be. Although these and a few other problems need to be solved before the UNOPAR is completely practical in industry, the problems can be more easily solved because actual measurements of what is occurring in all of its facets in the performance of work are obtained. Such research work is not possible for all motions with any other measuring procedure technique or device in this field.

Because the UNOPAR gives the actual measurement of operator per-

formance, many uses and benefits can be expected in the motion and time study field, as well as in other areas. Eventually many other disciplines which make studies of human being performances might be able to use such a device. A brief review of some of the possible uses of the UNOPAR is given below. In direct relation to time study, it should be noted how the various problems mentioned above in relation to time study procedure might be readily solved.

1. For study of motions. Many gaps exist in our knowledge concerning what a motion is, how it is performed, what its components are, etc. For example, just what happens when a body member positions an object, or assembles it, etc. is not known. Because the UNOPAR measures velocities of motions performed as slow as is possible to move, and because it will be able to record the exact position of a body member at any point, and the exact distance it moves, information concerning the performance of all motions can be obtained.

2. For study of motion patterns. Any operation is made up of a series of motions put together one right after the other. Or, in some cases, in combination. The effect of one motion on the performance of another motion is not known and, in most cases, research has indicated that there is an effect, but what it is exactly has not been determined. Learning more about the relationships of the various motions to each other, and evaluating the net effect of these relationships, should help devise better principles of methods design for use with establishing good methods on operations.

3. For evaluation of different methods for an operation. Although there are some techniques which can be used to help evaluate different methods, in almost all cases different methods for an operation which are "close together" are very difficult to evaluate. Actually, methods which are truly 15 to 20 per cent different may avoid detection of the best method because of the errors in techniques for evaluation. From the increased knowledge of motions and motion patterns, and from measurements of actual performances, evaluation should be better founded and more easily made than ever before.

4. For study of fine differences in method between operators on the same operation. The problem of subtle methods differs between operators on the same operation has confounded many a practitioner. Most of these differences are very small and present techniques do not permit an adequate analysis of the different methods. Better understanding of individual differences (and their possible causes) and better training techniques (aimed at those motions and cycles which present the most problems for the "poorer" operator) can result from the detailed information obtained by the UNOPAR. Likewise, this feature should reduce greatly the arguments between labor and management about what operators can, or can not, do.

5. For time study methods description purposes. After enough information about motions, motion patterns and individual operator differences is obtained, it should be much easier than at present to select the "proper" method (for performance level, training, etc.) to be recorded for the operation. This was one of the problems mentioned above in conjunction with methods descriptions and the UNOPAR offers a procedure for recording great detail about a method. This

does not mean that the velocity and acceleration plots represent the only method (or plots) which can, or should be used for the operation; indeed, many of the research projects performed at the Washington University Motion and Time Study laboratory have shown that individual operators differ significantly among themselves. What this does mean is that the velocity and acceleration points can represent a possibility of quantitative methods description which can form the center point of a range acceptable as the "same method." For example, a motion may be recorded for methods purposes as taking X units of acceleration (or velocity or any other unit of methods measurement that may be devised from the UNOPAR record) plus or minus 15% (or 10% or 20%, etc.). Thus, the UNOPAR with information about time, velocity, acceleration, position or direction and distance may well establish not only the most detailed procedure for methods description, but a quantitative technique as well.

6. For detecting sameness of, or changes in, method. This refers to the problem mentioned previously as a factor influencing adequate methods description. When a quantitative procedure for describing methods (or even just using UNOPAR plot records if the quantitative procedure is not developed) is used, this problem will be solved more easily and correctly than with any procedure available today. Obviously, the effects of these two uses alone should greatly improve present labor-management relationships.

7. For accurate timing. The UNOPAR has a constant speed tape to provide accurate timing of motions and elements with the smallest, practical time unit being .000133 minutes. The speed of the tape can be changed to reduce or increase timing accuracy, but the recorder runs at a constant rate at whatever speed is selected. Therefore, even though greater accuracy of timing may not be required, the UNOPAR can be used to obtain the desired accuracy. It should also be noted that the timing done here is an actual record rather than an observed record recorded by a human being.

8. For evaluation of operator performance (pace comparison or rating). Eventually all of the information about motions and activities of operators will provide the key to the accurate rating of operator performance for purposes of time study. The present hypothesis suggests that the acceleration and deceleration components of motions will be the major components of a relationship with the desired measure of operator performance. Although unions could, and would, participate in the selection of the standard amount of "acceleration-deceleration" units, the UNOPAR would then make accurate measurements in terms of these units. The effect of such a device on labor-management relations would be great with the virtual elimination of this error source in time study.

9. For improving the accuracy of other procedures for pace comparison or rating. Even though the UNOPAR may eventually be used for accurate pace evaluation or rating, it probably will not eliminate all pace comparisons or ratings with some of the more commonly used procedures. For example, low volume work, or some crew activities, of gross body motion operations would not usually require the accuracy of UNOPAR measurements. Yet the performance of the operator must be evaluated. Therefore, other pace comparison techniques will almost always be used (this is similar to other measurements, like linear, where the micrometer is not used all the time although it is

much more accurate than the yardstick). The UNOPAR would be used to determine accurately the pace of operators used for establishing practice pace comparison motion pictures. At the present time the usual training, or practice in pace comparison, consists of the time study people viewing motion pictures which have a number of different operations portrayed, each performed at a series of different speeds. The time study personnel make a pace comparison for each speed of each operation which is then compared to "actual" values determined from the time values for the different speed sequences and somebody's or some group's impression of what the pace comparison should be. If the UNOPAR is used at the time the pictures are taken, then actual values of pace are obtained making the practice sessions more valuable and developing better time study personnel with whatever procedure is being used. In addition, if motion pictures are used in any way in the actual establishment of standard pace or rating, then the UNOPAR would help make the motion picture representation of standard more accurate than before.

10. For determining accurate job difficulty measurement values. Because the UNOPAR would only measure the actual pace of an operator, regardless of the difficulty of the job, some procedure must be made to measure the amount of difficulty present in the job. Therefore, accurate values for the measurement of job difficulty are necessary. Generally, difficulty reduces the maintainable pace of an operator on an operation and difficulty values are determined from a large number of operations to be applied to all operations. Since pace, or speed of motion, is directly involved in the concept of difficulty, it follows that an accurate measurement of differences in pace is needed; the UNOPAR should fill this need.

11. For more accurate irregular occurence, delay and "machine time" allowance determination. These categories usually define where and how much additional time should be put into the final standard time. Some of these categories depend on the performance of the operator in relation to specific external or operation conditions. For example, some machine time allowances are based on the cyclic idle time concept, which is based on the amount of time during which an operator does nothing (all, or part of machine time) which then permits the operator to perform at a more rapid pace during external or manual elements. Since pace is involved, the UNOPAR can do a more effective job of determining the necessary values than other procedures. This likewise applies to some of the other allowance categories.

12. For the study of "fatigue." The fatigue concept has plagued the time study procedure and literature for some time. Although some feel it should be included in time study allowances, and some do not, an intelligent answer will depend on more accurate measurements of the effect of length of time of performing an operation on the pace of the performance. Present indications show that pace (actually production time per unit) does not vary as the length of time (day) performing the operation increases. However, much information not now available about performance of individual motions, motion patterns, elements and cycles, would help greatly to clarify this issue.

13. For study of predetermined motion times. Much has been writ-

ten about this area in the past few years. There are many benefits to be derived from the use of predetermined times and, at the present time, there are many pitfalls and dangers in over-extending these limited uses. Probably the most important reason for this is the lack of basic information regarding the motions themselves, and exactly how they are performed, as well as how they are interrelated into a motion pattern for the performance of an entire operation. Not only will the UNOPAR eventually tell more about the times for individual motions, but it should also answer the many questions concerning the accuracy and time standard usefulness of the time values.

14. For other uses in industrial engineering. Many facets of industrial engineering depend on time standards. Anything that can be done to make time standards more accurate will help other areas of industrial engineering like cost accounting, production control, production planning, plant layout, materials handling, etc.; especially useful will be the information regarding performance of motions in relation to the design of jigs and fixtures, controls for jigs and machines, etc. to permit the most effective use of the human being. Even then, the eventual usefulness of UNOPAR is unlimited.

15. For use in other branches of science. Many fields deal with the study of human beings as directly related to physical activities. Some branches of physiology could easily desire information regarding the external features of performing different tasks. Psychology is frequently interested in learning about the reaction of operators' motions and motion paths as related to certain psychological stimuli. The field of biomechanics is likewise interested in the relationship between man and machine, and much of their work depends on information concerning what an operator does and the time or pace for the performance. Even athletics are directly concerned with motions, motion paths, and learning more about what an athlete does in performing a test. All of these areas would be greatly assisted by the information of time, velocity, acceleration, distance, and position or direction provided by the UNOPAR.

The ability to measure accurately the performance of operators is a large step toward the goal of making the whole field of motion and time study, and work measurement in particular, a more objective activity. The UNOPAR has indicated that objectivity probably will be injected in this area shortly. It is still in the research state of development and testing, with the day for industrial testing approaching more rapidly. With this objectivity, management will benefit through more accurate information for all of the area where time standards and operators are important. In the same way, labor-management cooperation and relations should improve because of the more accurate data available for discussing these points which have previously caused strife and friction. It is important at this stage, however, to warn that the UNOPAR has not fully arrived, and that when it is fully developed, it may not do everything expected of it. However, it represents such a radical change in concepts of measurement of human performance, that it can be expected to revolutionize many aspects of industrial engineering. Even at the present levels of accuracy, the information available from the UNOPAR is so much more accurate than that available from other procedures or techniques that much can be learned in the motion and time study area.

Likewise, the concept of applying electronics to industrial engineering techniques should receive much more emphasis and importance in the very near future.

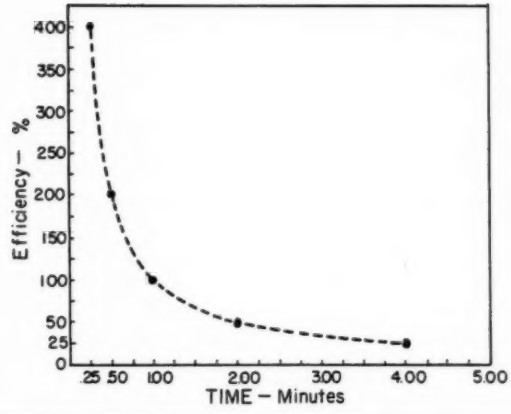


FIGURE 1

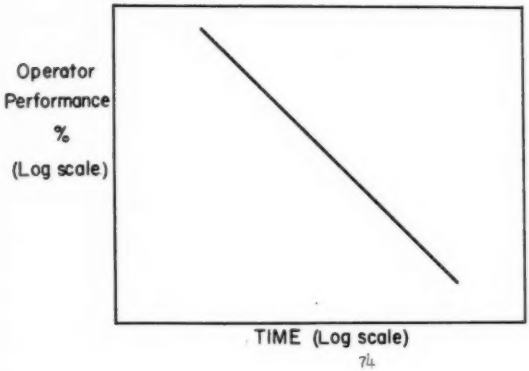


FIGURE 2

FIGURE 3

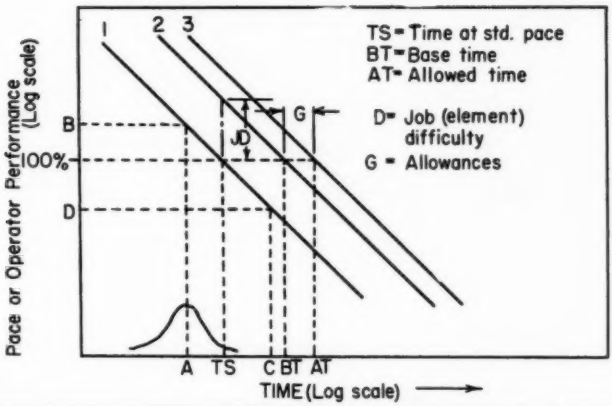
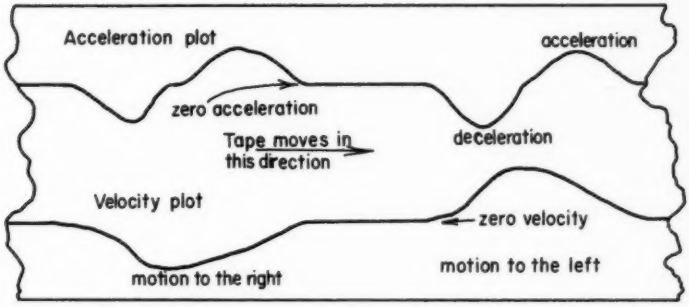


FIGURE 5



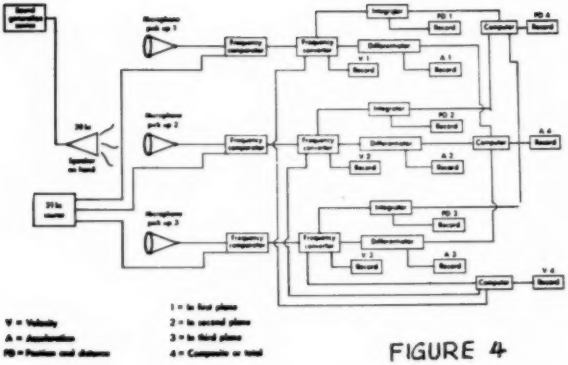


FIGURE 4

NOTES

USE OF CONTROL CHARTS IN INDUSTRIAL ENGINEERING

by

Joseph Movshin

Quality Control Manager, Ramsey Corp.

In discussing control charts, we are duty bound to indicate that a control chart is a statistical technique. This is somewhat of a foolhardy thing to do. As we all know, statistics falls into one category of the three basic kinds of untruths -- namely lies, damned lies, and statistics. We all know that statistics is that dangerous subject as a result of which the man was drowned walking across a stream averaging two feet deep.

Furthermore, those who use statistics develop a suspicious nature about all information. This tends to be a great source of annoyance to their fellow workers. People using statistics begin to act somewhat like the psychiatrist whose years of contact with his patients have convinced him that no one is fully normal. In fact, it got so bad that, when one day an acquaintance wished him a good morning in passing, the psychiatrist turned to a friend and said "I wonder what he meant by that?"

Nevertheless, in recent years control charts and other statistical methods have become increasingly important tools in the kit of the industrial engineer.

In 1931, Dr. Walter A. Shewhart published his classic text, Economic Control of Quality of Manufactured Product. For many years, this basic work on statistical quality control was merely an interesting study for a relative few. World War II saw tremendous development in this field. Because of economic necessity, shortage of manpower, and need for better and more uniform quality, these techniques were developed and introduced to industry by the Armed Forces and other agencies of the Government. Since that time, the American Society for Quality Control, many schools, and interested industries have conducted programs of training and development in the techniques necessary to apply statistical methods to industrial problems. At the present time, our own publication, "The Journal of Industrial Engineering", has articles on the application of statistical methods to Industrial Engineering techniques and problems in practically every issue.

It might be interesting to comment on what is a statistic. Many texts have provided quite elaborate definitions of this term. Many of these add confusion as well as description to the word. To me, a statistic is merely a single number that tells something about a bunch of numbers. The average tells where the middle is; the range, or standard deviation, how spread out the bunch is. Other statistics, such as maximum, or minimum, tells what the biggest and littlest of the bunch might be. With this definition, the concepts of statistics may be described in the kind of terminology that can be discussed in the shop without drawing blank stares and shaking of heads. The ability of Statistical Quality Control to present its techniques in such terms is one of the reasons for its success.

Our statistical approach is based upon the concept of a constant system of chance causes. This describes a particular combination and arrangement of men, materials, methods, machinery and measurement. Such a system is designed to produce a given result in terms of a product or service characteristic, and is evaluated by a specific measurement. In this sense, measurement could be a ranking, a count of some attribute, or the usual physical measurement.

In a constant system of chance causes, a great many factors contribute to the overall variability. Each of this multiplicity of factors varies essentially independently and randomly within its own limitations. The total effect of these produces the inherent process variation. We cannot separate the individual factors that make up the result in a particular measurement. We can, however, predict the overall effect of all the random variations. We cannot explain why a particular measurement occurred. We do know essentially what all the measurements will be like.

Perhaps we can illustrate a constant system of chance causes very briefly with a pair of dice. If we throw a single die, any value from one to six might occur. We say chance produced the result. If we would chart the die's position in space; impart to it a given velocity and direction; knew the properties of the die material, and the material upon which it would bounce; we could predict the angle of impact and all subsequent motion. We could predict mathematically which face of the die would be up for any given initial starting condition. In fact, it is my understanding that with practice, some individuals have achieved this physically to a remarkable degree.

Since we do not know all of these factors, and since they operate essentially randomly, we cannot predict a given throw. We can, however, state that over a great many throws, each value will occur one sixth of the time. This is a prediction of the frequency distribution of a large number of throws of a single die. It is also the probability of occurrence of each value.

Using two dice, we can also predict mathematically the probability of each total from two to twelve. Experience may have given some a feeling for these probabilities. For example, an individual in a game of chance with the dice might become quite excited if his opponent managed to roll eight sevens in a row. This is not because it is impossible to roll eight sevens in a row. A feeling for the probability of the dice has resulted in a strong belief that it should not happen too often. In fact it should happen so rarely that if it does happen, an investigation of the circumstances is in order. Our action decision is governed by what does happen relative to the probability of the event.

While it is physically impossible to throw a thirteen with the dice, the presence of such a value in our theoretical illustration would also be something that would not normally be expected of the system we have. It would, therefore, be cause for investigation.

Let us consider the Control Chart, (Exhibit II). The most popular chart is generally based on the averages and ranges of small samples. The range

is used in place of the standard deviation for simplicity. Actually, two charts are used. The first of these, the Average Chart, watches the location of the mid-value of the pattern of variation. The Range Chart maintains a continual watch over the spread. With the average and range under constant surveillance, we are in a position to know how the system is performing at all times.

Setting up a control chart is relatively simple. Small samples or subgroups are drawn at periodic intervals of time. The averages, ($\bar{X}$), and ranges, (R), of these small samples are then plotted on the charts. The center line of the $\bar{X}$ chart is the grand average, ($\bar{\bar{X}}$), of the subgroup averages. The average of the ranges, ($\bar{R}$), of the small samples provides the basic measure of spread for the establishment of control limits. Calculations of the control limits are relatively simple. For the average chart, the control limits are placed at $\bar{\bar{X}} \pm A_2\bar{R}$. The upper control limit for the range chart is $D_4\bar{R}$, and the lower limit is $D_3\bar{R}$. The process standard deviation, (σ), may be estimated from $\sigma = \bar{R}/d_2$. The factors A_2, D_4, D_3, and d_2, are based upon subgroup size and are available in tables in most books on Quality Control.

Control limits are based upon the average range. As this is a measure of the inherent process spread, the control charts may be said to compare the observed variations as the process operates with its inherent variability. Any indication that the variability noted between subgroups is not consistent with that predictable from the process variation is taken to mean that some factor is disturbing the basic system. This situation is described as an assignable cause, and is generally of such a nature as to be identifiable. The causes of variation inherent in a process are random factors. The effect of these are not separable.

Actually, control limits are probability limits. The factors used set three standard deviations (3 sigma) limits, or about a .997 probability. There is only about a three-in-one-thousand chance that a point will occur outside the limits and yet belong to the same system of values. The fact that the probability of occurrence for a point outside the control limits is low is used as justification of the assumption that an assignable cause was present. We will be wrong about three times in a thousand in this assumption when we use three sigma control limits. The chances are so great that some external factor has caused the observed points, that it is well worthwhile to search for it.

Indications of the presence of an assignable cause are:

1. Points falling outside of the control limits.
2. Runs of points on one side of the average.
3. Trends, or continual changes in one direction of a series of points.
4. Any non-random behavior on the part of the successive plottings.

No comment is necessary on the success of this control chart technique in the Quality Control field. The adoption of the control chart by so many

industries, the growth of the American Society for Quality Control, the increased volume of literature on its use and advantages, testify to the place of this technique in modern industry.

The same factors that make the control chart so successful in Quality Control are present in many problems in other areas of Industrial Engineering. The basic situation is this: A system is set up to accomplish a definite purpose. The system may be a simple hand operation, a complicated machining operation, or an entire production process. The process might be one producing services, rather than individual items. Cost accounting, production control, and billing, are all such systems.

In each case, the results are repetitive, with a stream of product leaving a work center for customers, or a stream of papers and numbers leaving for control or directive purposes. A system has been set up whereby a given result is to occur. The results may be recorded in terms of a number which measures a particular characteristic of the process.

From this continuous series of measurements, we should like to be able to answer two fundamental questions about the process:

1. Is the process essentially consistent in terms of the inherent factors of variability, or is there evidence that external factors or disturbing the basic system?

2. If the process is consistent and does not show evidence of assignable cause, then is the level of this measurement, and its normal variability about this basic level, satisfactory for our purpose?

These two questions are implied by another question which is often the immediate point of interest. Does a particular sample show any indication of a basic change in the pattern of activities?

These questions, of course, are answered by the control chart. The grand average is the level of our operation. The average range gives us our measure of spread. The control limits associated with both charts check each particular subgroup for consistency. We can, of course, compare the grand average and the standard deviation with what we hope to accomplish in the particular characteristic investigated.

Perhaps we can illustrate the control chart approach in a typical situation. Exhibit I is a time study of a relatively simple operation. Is this time study a satisfactory basis upon which to establish a standard? Do the observations represent a consistent operation and measurement with only the inherent variability present?

We would like to know, also, how close our estimate of the average time may be to what might be called the correct or true time.

Exhibit II shows a control chart for our time study. There is evidence of assignable cause present. We, therefore, know that something has occurred which should be investigated. This study should not be used until we have

satisfied ourselves that any external factors affecting the process have been eliminated.

It is accepted practice in time study work to eliminate from the study those values which are clearly not the result of the normal process activity. More often than not, this is done merely by observation. For very extreme values, this may be satisfactory. In many more cases, however, the justification for the removal of a given observation is questionable. Where relatively few measurements are available, it is difficult to judge from the values alone whether or not one or two apparently different readings should be discarded. Often, as in our example, no particular value is obviously rejectable. The control chart, however, does clearly question certain cycles.

For the control chart of this time study, our sample, or subgroup, was chosen as two successive cycle times.

In this situation, the basic control chart question then becomes: Is the operation of the system producing our time studies consistent with the basic variation as measured by the difference between two successive cycles? We are assuming that there is only a minimum chance that anything except normal process variation will produce the difference between two successive cycles. This is our best means of estimating the process variability. If enough time studies were available, three or four successive cycles could be used as our subgroup. It is desirable to have over fifteen subgroups or samples in the control chart. In many cases, this consideration will help determine the subgroup size.

If we would assume for the moment that no assignable cause had been present in this study, we can consider our second problem. How close to the correct average time is the one found? Our observations, of course, are merely samples from all possible cycles of operation of the process. How well may our sample be expected to represent the source?

Another statistic, the standard error of the mean ($\sigma_{\bar{X}}$) is used for this question. This statistic measures the variability of the averages of samples of the size we are concerned with; in this case, the average of 30 readings. Using this measure, we would find that for thirty samples, our true time would be expected to fall within the limits $1.0947 \pm .0056$. Again, there is a probability associated with this determination. For this type of problem, a 95% probability is generally used; and was used in determining the value indicated. The chances will be ninety-five in one hundred that the true value will lie between 1.0891 and 1.1003. If this spread is too broad for our purpose, we must take more samples to pinpoint the time with a higher degree of precision.

Another interesting problem is that of comparing time, or some other characteristic of two standard methods. If the numbers of observations are relatively large, a control chart can be made of the measurements of each method. The averages and measures of spread of the two can be compared directly on the charts. If the number of observations is relatively large, say over 50, the control charts will provide very accurate estimates of the differences in the two methods. If, on the other hand, the number of the number of observations is limited, other statistical tests must be used.

For example, in Exhibit III, Process A shows certain values on a destructive test of a given part. Process B values are also indicated. Is there any significant difference in the two processes with respect to this particular characteristic? We can answer this question by the use of two simple tests for significant differences, one for averages and one for spreads. These calculations are also outlined in Exhibit III. In this particular illustration, there is no significant difference, and other considerations would dictate the choice of one method over the other.

Again, probability is our criteria. What we are doing in these tests, is estimating the probability that chance alone would produce as great a difference between the groups as that observed. In general, a probability of occurrence of 5% or less is considered significant. If chance alone has a 5% or less probability of producing a difference as great as that noted, we assume that chance did not produce it. In such a case, we say there is a basic difference in the two processes. This can exist either between the process averages or between their spreads.

As a point of interest, two different estimates of the standard deviation are shown. One is found from the range, the other calculated directly from the data. Because of the effects of sampling variation and the fact that the range is not the best way of estimating the standard deviation in a small sample, both are found in this case. With small samples, we feel better if the standard deviations found from the two methods are in close agreement.

Another interesting application of control charts to an important problem was one of departmental cost control. In this particular situation, monthly cost figures are provided for individual departments in a plant. These showed the typical up and down variation normally encountered. As is customary in such cases, low figures bring their sighs of relief, and high figures their questions and anxieties. Of course, in many cases there is no significant difference between the high and low figures that show the normal month to month variation. The questions that are important in this area are: What is the average level of operation; and at a given moment, in what direction are the costs heading? A control chart can answer these questions in an effective manner.

Unfortunately, however, one cannot merely plot such cost figures. In most manufacturing departments, costs are related to the amount of activity. It is necessary to compare the costs only with due consideration of the relative outputs generated in each case. To accomplish this, an interesting device was employed. First, a month by month history of cost versus output was plotted. The past year could be used and considered as one period. Exhibit IV shows such a chart. The method of least squares was then used to calculated the line representing the relationship between cost and output. Output, of course, may be expressed either as the number of units or some other measure of over-all activity. It is then possible to calculate the expected limits of variation about this line.

Again, we calculate a standard deviation. In this case, our values are the difference between the individual cost figures and the line of least squares. The same basic information may be obtained by treating this situation as a correlation and calculating a line of regression and confidence limits. This is,

of course, the statistical way of saying it; the other way also works fine. A 95% probability, which corresponds to two standard deviation limits of variation, is often used for confidence limits in such a case. Confidence limits mean that you are confident -to the degree indicated by the probability- that no value will go beyond these limits. Such limits were calculated and are shown in Exhibit IV.

We know that there is only a one-in-twenty chance of any one value being further away from the mean than the two sigma limits, if the overall system generating these costs is essentially consistent. In this particular case, an essentially consistent system is indicated. If this were not so, it would be highly desirable to attempt to find out why the non-conforming cost figure occurred. If the assignable cause point is for too large a cost, perhaps a source of loss can be uncovered. If it is too small, perhaps a desirable situation might be recognized and incorporated into our standard practices.

From the line of relationship, we can determine the expected cost for any given output. Each month, then, we will determine from this chart the difference between the expected and the actual. This will be plotted on our control chart, Exhibit V. Here, the desired average is zero. This would indicate no deviation from the expected. The two standard deviation limits of variability indicate the normal expected spreads about this value. We have merely converted our variable cost line to the average of a control chart. Each month's figure is then immediately checked to see whether or not it conforms to the pattern. If it is within the expected limits of variability, there is little that can be said about it. If it is not, we are still close enough in time to locate either the source of trouble, or the desirable occurrence. In addition to knowing about the presence of an assignable cause, the saving in frayed nerves and unnecessary excitement may also be appreciable. We know when not to look for something that isn't there.

The charts we have discussed present a picture of a process situation. The effectiveness of the pictorial representation of a statistical situation is actually quite well known. Annual statements of most companies, Government reports, and sales appeals of all sorts use such devices. From an Industrial Engineering standpoint, one of the simplest, yet most effective statistical tools for the presentation and analyzing of data is primarily pictorial. I refer to the frequency distribution, (Exhibit VI).

From the frequency distribution, itself, without the use of any arithmetic, we can get a good "feeling" of the average or level of the system, of its spread, and of its basic stability. A frequency distribution is one of our most important tools for representing a large number of measurements and extracting from them a general picture of the process.

Perhaps we can illustrate the concept of graphic presentation of statistical data with another example. It is important for a Personnel Department to know how their average wage compares to wages paid in the area. This is accomplished through direct interchange of information, manufacturing association reports, Chamber of Commerce publications on real earnings, and similar sources. In a given plant, however, it is not enough to compare the book wage scales with the area wage levels. The situation of actual employees with respect to their wage scale midpoints must be considered. A frequency distribution, either by departments, job classification, or the overall

company can show such a picture.

In our example, the difference between each wage paid and its range midpoint is expressed in percent of the midpoint. These percent differences are shown in the frequency distribution in Exhibit VI. As might be expected, the distribution has quite a few individuals at the mid-value with extremes occurring at both ends.

The normal course of events produces a continual shifting of this distribution. When an employee transfers from one job to another, he usually transfers to a better job. He thus will be changing from the higher section of one range to the lower of another. New employees usually enter at the lower part. This constant rotating of personnel produces fluctuations in the overall average of the distribution. To watch this fluctuation, the average difference of all employees is plotted monthly on the chart shown in Exhibit VI. The averages of those above the midpoint and the average of those below, are also plotted as a measure of our within range spread. As most personnel directors will testify, enough spread is necessary for incentive while too much is undesirable. With this chart, we are in a position to maintain a continual watch over our wage situation.

The graphical technique of the frequency distribution can well be applied to almost any data collected by the Industrial Engineer. It is actually a fascinating sort of thing. Almost without exception, the presentation of information in this form leads to new and interesting speculation about the source of the data. Problems in measurement and counting tend to be pin-pointed, as are characteristics of the source of the data itself. Actually, the frequency distribution and the control chart are often very effective supplements to a time study, methods analysis, job evaluation, cost study, or budgetary problem. The use of a control chart or frequency distribution as supplemental information to a time study with respect to the quality of the product is something that certainly should be mentioned at this time.

Most texts on time study and most instructors in this field indicate that in making a time study some information as to the quality of the product should be obtained. Usually, the matter is dropped at this point. Because of this fact, by far the overwhelming majority of methods and time studies are made with superficial, if any check on the quality of product. The examination of one or two pieces is not a measure of quality. The ideal situation would be to have inspection personnel run a control chart or a frequency distribution on important characteristics as the time study is being made. A permanent clear description of the level of quality, the variation about this level, and the consistency of the operation are presented. Again, indications of assignable causes may be found. If these are present, the desirability of setting a standard on this process is highly questionable. Would we want to set a standard on an operation when the quality is subject to unexplained non-inherent variations that have occurred, and which may occur to an unpredictable degree in the future? Of course, the answer is no, but very often exactly this happens. We might also be interested in asking what percentage of the product is scrap with the given method or standard time. Perhaps it is cheaper to use a costlier method, but which may more than make up for the difference in the additional value of the product.

The techniques we have discussed have not applied the more formidable statistics and statistical mathematics. In a great many cases, simple arithmetic is all that is used. Of course, it is necessary that we understand the basic techniques and underlying principles of statistical methods.

At the present times, a great deal of even the more exacting work in the application of statistical methods is being done on the basis of "quick and dirty" techniques. "Quick and dirty" statistical methods are simplified adaptations of the exact procedures. In these simplifications, untested assumptions are made, and individual steps may be altered or omitted. For example, in many cases, the use of the range in place of the standard deviation is not strictly justified, but is an effective tool.

In our particular case, several steps and assumptions underlying the examples presented might be questioned by the pure statistician. We have sacrificed something in the probability of error for our decision, and in statistical exactitude for simplicity of approach. Nevertheless, for all practical purposes, most of these methods are well within the limitations of accuracy of the data with which we work. It is on this basis that I feel that the "quick and dirty" approaches are justified. May I stress again, however, that a reasonably sound background is necessary for the successful application of the abbreviated techniques.

In these comments, we have only touched upon a few of the examples of the application of control charts and statistical techniques to Industrial Engineering. In the February 1955, Factory Management and Maintenance, Dr. Gerald Nadler discusses from a probability standpoint "How Many Time Study Readings to Take". Many articles are available on operations research and its application to production control and production scheduling. Much is available on work sampling as applied to various areas of methods and time analysis. Weaknesses of production processes are analyzed through operations research techniques. Cost control has been a fertile field for current writers. Ratio-delay methods, based on probability and random numbers is included. Measuring down-time with another form of control chart, the p chart, is discussed in the November 1954 Iron Age. Rating ability has been the subject of numerous papers advocating control chart and statistical techniques.

Perhaps the best summing up of these many statistical methods and their possible areas of application is in the February 1953 Journal of Industrial Engineering. Dr. Howard P. Emerson, in his article "Mathematical Foundation for Industrial Engineering" outlines a great many statistical methods and techniques, and the Industrial Engineering applications to which they apply.

Some twenty-one separate statistical techniques are listed, along with some twenty-nine areas of application. Actually, in each case, only one or two specific areas is indicated as an example for a statistical technique. A great many more could be listed. Perhaps in closing, I can well quote Dr. Emerson in this article when he says, "On the basis of all this, I believe the Industrial Engineer should 'latch on' to statistical mathematics as the most productive of the mathematical fields".

2/5/55 54-161 EXHIBIT I / /

| | | |

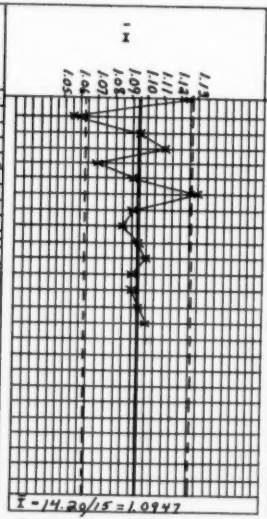
EXHIBIT II

DIMENSIONAL CONTROL CHART

Study No. 54-161

Dept.	Operation Time Study	Dim. Mean. Cycle Time	Inspector No.
Date 2/5/55	Machine No.	Operator No.	

TIME	LOT NO.	SIZE	TOLERANCE	MEASUREMENTS OF SAMPLES 1	2	3	4	5	SUM OF MEAS.	$\bar{X}$	R
				1.14	1.11				2.25	1.125	.03
				1.05	1.06				2.11	1.055	.01
				1.10	1.09				2.19	1.095	.01
				1.11	1.11				2.22	1.11	0
				1.10	1.04				2.14	1.07	.06
				1.09	1.09				2.18	1.09	0
				1.12	1.14				2.26	1.13	.02
				1.09	1.09				2.18	1.09	0
				1.08	1.09				2.175	1.085	.01
				1.12	1.07				2.19	1.095	.05
				1.11	1.09				2.20	1.10	.02
				1.10	1.08				2.18	1.09	.02
				1.08	1.10				2.18	1.09	.02
				1.09	1.10				2.19	1.095	.01
				1.10	1.10				2.20	1.10	0
TOTALS											

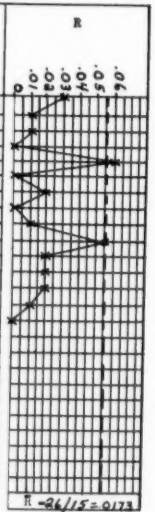


$\bar{\bar{X}} = 14.20/15 = 1.0947$

$CL_{\bar{X}} = 1.0947 \pm (.0173 \times 1.88)$

$UCL_{\bar{X}} = 1.127$

$LCL_{\bar{X}} = 1.063$



$\bar{R} = .26/15 = .0173$

$UCL_R = .0173 \times 3.27$

$UCL_R = .056$

$LCL_R = 0$

EXHIBIT III

Test No. X 193

PROCESS A	PROCESS B
25.4	25.3
25.6	27.0
24.3	25.6
23.5	23.6
26.6	24.8
26.1	22.2
23.9	21.7
24.9	22.3
23.9	22.8
24.6	23.9
10 / 248.8	10 / 239.2

$\bar{X}_a$ = 24.88
R = 3.1
σ_a (Estimated from R) = 1.01
σ_a (Computed) = .98

$\bar{X}_b$ = 23.92
R = 5.3
σ_b (Estimated from R) = 1.72
σ_b (Computed) = 1.64

TESTS FOR SIGNIFICANT DIFFERENCES

Averages are significantly different if $\dfrac{\bar{X}_a - \bar{X}_b}{\sqrt{\sigma_{\bar{X}_a}^2 + \sigma_{\bar{X}_b}^2}} > 2$

$$\frac{24.88 - 23.92}{\sqrt{(.98)^2 + (1.64)^2}} = \frac{.96}{1.91} = .50 < 2$$

No significant differences in Averages

F TEST FOR STANDARD DEVIATION

$$F = \frac{S_b^2}{S_a^2} \qquad S^2 = \frac{n}{n-1}(\sigma)^2$$

$$S_a^2 = \frac{10}{9}(.98)^2 = 1.067$$

$$S_b^2 = \frac{10}{9}(1.64)^2 = 2.988$$

$$F = 2.988 / 1.067 = 2.80$$

From Tables of "F" Distribution:

For n_a = 10 n_b = 10

at .10 Probability level, F ratio = 2.44

at .05 Probability level, F ratio = 3.18

No significant difference in standard deviations.

Department xyz EXHIBIT IV

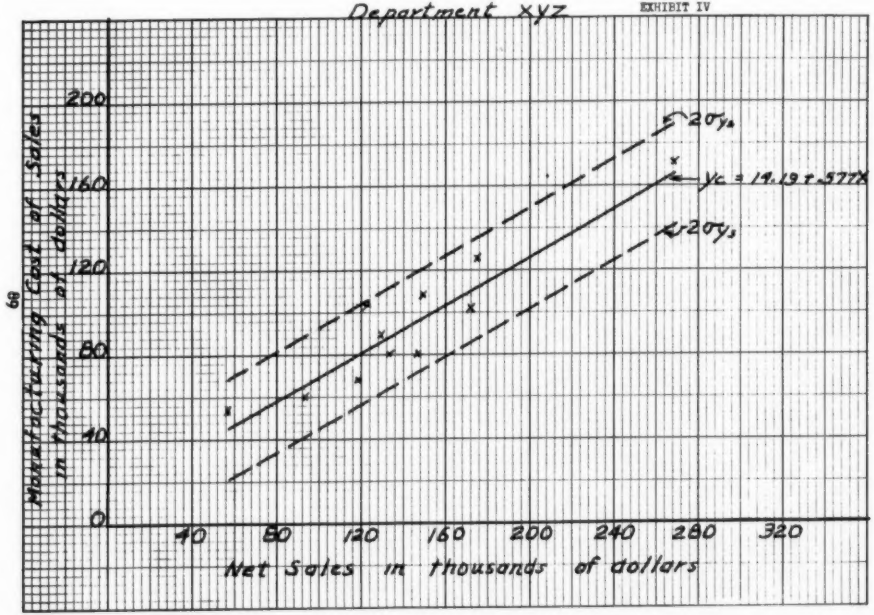


EXHIBIT V

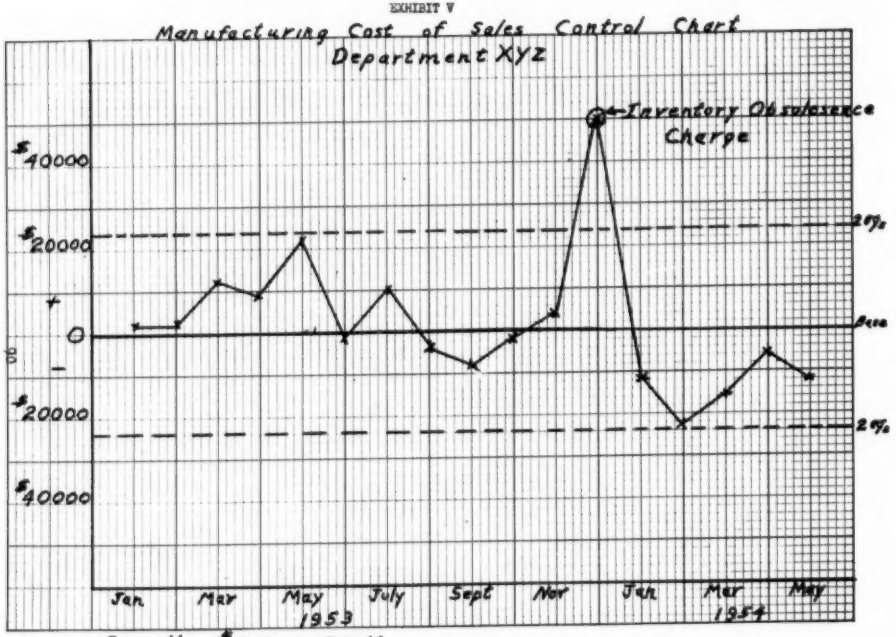
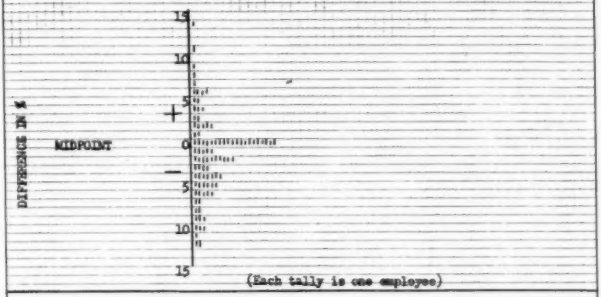

Manufacturing Cost of Sales Control Chart
Department XYZ
Inventory Obsolescence Charge
$40000
$20000
+
0
−
$20000
$40000
2%
Base
2%
Jan
Mar
May
July
Sept
Nov
Jan
Mar
May
1953
1954
Base: Yc = $14190 + .577X

EXHIBIT VI

SALARY OF GROUP H EMPLOYEES COMPARED TO RANGE MIDPOINTS

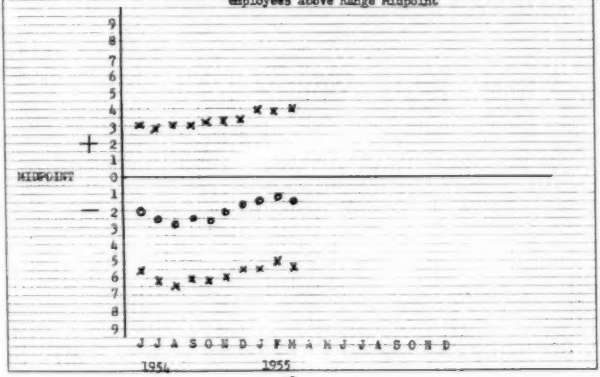
FREQUENCY DISTRIBUTION - DECEMBER 1954



CONTROL CHART

O Average difference in % of all employees in Group H

x Average difference in % of all employees below, and of all employees above Range Midpoint



Base: Yc = 4.190 + .577X

NOTES

May 12, 1955

"HOW TO MEASURE FORK TRUCK PERFORMANCE"

AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS

SIXTH ANNUAL NATIONAL CONFERENCE

BRUNO A. MOSKI

THE YALE & TOWNE MANUFACTURING COMPANY

PHILADELPHIA, PENNSYLVANIA

Ladies and Gentlemen:

Your Conference Theme, "A Panorama of Industrial Engineering - - - The Latest in Techniques", has a powerful appeal to the industrial engineering practitioner who is constantly seeking to increase the value of his services to management.

This paper, "How to Measure Fork Truck Performance", is a miniature panorama in itself, as it includes the following topics which are of interest to the industrial engineer:

1. Recognition by the materials handling industry of the need for standard time data.
2. Cooperation between industry and education in the development of standard time data.
3. Practical use in industry of a laboratory tool.
4. Contribution to the field of predetermined time standards.
5. Practical examples of the use of standard time data for fork lift trucks.
6. Cooperation between industrial engineering and sales engineering in the application of standard time data.

We shall expand upon each of those topics, in turn.

Need for Standard Time Data

Materials handling is a relatively new industry.

It has progressed in direct proportion to the evolution in America from the era of slave labor, through the stage of cheap immigrant labor, to the full recognition of the dignity of the employee as an individual.

The place of man as a beast of burden has been taken by a skilled operator controlling the sinews of a fork lift truck.

The human effort of a laborer wrestling with loads of one hundred pounds or more, has been replaced by the mechanical handling of loads as high as one hundred thousand pounds, with the ease of a man driving the family car.

Frederick W. Taylor recognized the need for the measurement of the human effort of the laborer.

The materials handling industry has recognized that the need for measurement has increased since the unskilled laborer has been replaced by a fork truck operator with a fairly substantial capital investment at his command.

Cooperation Between Industry and Education

When our company undertook to develop standard time data for fork lift trucks we were fully conscious, however, that the validity of any set of standard time data developed by a single company, might well be challenged in a highly competitive industry.

We believed that it would be desirable to obtain the cooperation of an impartial observer, in the form of an educational institution, in order that the results obtained might be supported by modern statistical principles, and might be more generally accepted.

Accordingly, we completed arrangements with the Wharton School of Commerce and Finance, at the University of Pennsylvania, to conduct a study, with full access to the facilities of our plant and to those of many industrial and government plants using fork lift trucks.

Rather than go into further details regarding this project, we should like to show at this time a documentary sound film in color which covers the highlights of the study.

(Showing of motion picture film.)

Practical Use of Laboratory Tool

In the motion picture film, you noticed that memo-motion study was used to accumulate the raw data, for subsequent analysis in the laboratory.

As your Conference deals with industrial engineering techniques, we should like to dwell on this point for a moment.

We believe that Marvin Mundel, now at Marquette University, originated memo-motion study, for the purpose of conserving 90% of the film required in micro-motion study, and for the purpose of analyzing operations where increments of .01 minute is adequate.

Memo-motion study has found many applications in university laboratories, where it is highly desirable to maintain a full visual record of experiment conditions.

We believe that this project is the largest single study in existence at the present time, which has made use of memo-motion study under practical industrial conditions.

As a result of this study, we have had discussions with other large firms who are planning to utilize memo-motion study for the analysis of industrial operations.

Predetermined Time Standards

Copies of an article, "How to Measure Fork Truck Performance", have been distributed at this Conference, and are in your hands.

We should like to call to your attention, on pages 84 and 85, the basic truck motions and the corresponding time standards involved in the operation of a 4,000 lb. Electric Fork Lift Truck.

This table, with its definitions of the basic motions, constitutes a valid contribution to the field of predetermined time standards, comparable to the various plans with which you are generally familiar.

On pages 87 and 88, we have listed and defined the 27 operating variables which were isolated during the study, and which must be evaluated in each specific plant, in order to increase Basic Time to Standard Time.

Practical Examples

Both the motion picture and the magazine article include an example of the application of the data, as provided to us by the Wharton School.

In reviewing the results of the study, we believed that it was desirable to develop a standard technique for the application of the data, in order that the data might be of maximum practical value to industrial firms throughout the country.

Accordingly, we prepared a Work Kit for Application of Standard Performance Data for Fork Lift Trucks, copies of which have also been distributed, and are in your hands.

We should like to review with you the various exhibits included in this Work Kit.

(Detailed review of exhibits in Work Kit.)

In this review, we have discussed the application of the data to a typical industrial plant.

We wish now to review the results of a practical application of the data to a specific job in our plant.

We selected a Drive Axle Housing which we use in many of our Fork Lift Trucks.

Drive Axle Housings are received as rough castings from a foundry, spray painted with a coat of primer immediately after their receipt, stored in the yard until required, moved to the incoming-material area of a Machining Department, machined through all operations in a single Machining Department, and moved to Finished Stores.

The major transportation moves involving a Drive Axle Housing include:

1. Move (3) Bins from Spray Painting Conveyor to Outside Storage.

2. Move (3) Bins from Outside Storage to Incoming-Material Area of Machining Department.

3. Move (3) Bins from Out-Going Material Area of Machining Department to Finished Stores.

Before developing the basic time values, we analyzed the conditions in our plant which would influence the evaluation of the operating variables, according to the procedure outlined on pages 87 and 88 of the article.

We determined that in our plant, it was necessary to add to the basic time values, percentages which ranged from a minimum of 26% for the majority of elements, to a maximum of 33% for a few elements, in order to convert Base Time into Standard Time.

The major portion of these percentages is represented by 15% for Fatigue, or necessary rest and personal time for the operator, while the remaining portion is due to minor allowances for Carelessness, Battery, Traffic, Obstructions, Housekeeping, Sc heduling, Doorways and Intersections.

The additions of these percentages to the Basic Time values developed Standard Time values for Fork Lift Truck operations in our plant.

We then charted the actual motion paths for the major transportation moves in this example, in the manner demonstrated in Exhibits D and E in your Work Kit, but using Standard Minutes rather than Base Minutes.

The evaluation of the motion paths developed the following results:

Motion Path	Standard Minutes	Standard Hours
1. Move (3) Bins from Spray Painting Conveyor to Outside Storage	7.4412	0.124
2. Move (3) Bins from Outside Storage to Incoming-Material Area of Machining Department	9.8721	0.165
3. Move (3) Bins from Out-Going Material Area of Machining Department to Finished Stores	10.1192	0.169
4. Total Standard Time	27.4325	0.458

After we had charted the motion paths, and developed the Standard Time as described above, we then instructed a Fork Lift Truck Operator to perform the actual work for the entire example.

We took a conventional time study with a stop-watch for the full period of the example, levelled the actual time values, and added 15% for Fatigue, to develop Standard Time for the actual work.

The results of this conventional time study were as follows:

	Motion Path	Standard Minutes	Standard Hours
1.	Move (3) Bins from Spray Painting Conveyor to Outside Storage	8.2570	0.138
2.	Move (3) Bins from Outside Storage to Incoming-Material Area of Machining Department	8.3950	0.140
3.	Move (3) Bins from Out-Going Material Area of Machining Department to Finished Stores	8.9125	0.149
4.	Total Standard Time	25.5645	0.427

The variation in Standard Time, from 0.458 Standard Hours on the basis of Standard Time Data, to 0.427 Standard Hours on the basis of Actual Time Study, is 0.031 Standard Hours, or 6.8%.

We believe that the development of this practical example in our own plant, with the degree of accuracy indicated, is further proof of the validity of the Standard Time Data.

Beyond these examples, we should like to stress another valuable use of the Standard Time Data.

As stated in the Work Kit, Standard Performance Data for Fork Lift Trucks not only provides a method for determining your Fork Lift Truck capacity requirements, but it also provides a yardstick for the evaluation of your excess materials handling costs.

The careful analysis of Variable Factors in your specific plants can result in the determination of your excess costs resulting from poor pavements, inadequate aisles, poor lighting, poor housekeeping, aisle traffic, obstructions, grades, inadequate maintenance and other factors contributing to high materials handling costs.

It may be to your economic advantage to change certain operating conditions to take advantage of the potential reduction of excess materials handling costs.

In this respect, Standard Performance Data for Fork Lift Trucks has a certain kinship with monthly Profit-and-Loss Statements developed in conjunction with a Standard Cost Plan, in which Variation Accounts are used to point the way to decreased costs.

Cooperation with Sales Engineering

The last topic in our miniature panorama, "cooperation with sales engineering", is one which should be of interest to all industrial engineers.

As industrial engineers, we appreciate the value of measurement and control of time and effort in all phases of the industrial organization structure.

We always welcome an extension of this point of view in other departments of the organization.

With this study, we have placed an industrial engineering tool in the hands of our sales engineers.

Our sales engineers, in turn, are in a position to explain this tool to management executives and industrial engineers in the plants of our customers, in order that our products may be utilized to the maximum advantage.

The net result is to strengthen the practical goodwill existing between our company and our customers, as a result of the cooperation between our industrial engineers, our sales engineers and the management organization of our customers.

Summary

In this paper, we have outlined the development and application of Standard Performance Data for Fork Lift Trucks.

We believe that we have provided you with a basis for the practical application of the data in your own plants.

It is our sincere hope that you will obtain tangible benefits from this discussion of. --- "How to Measure Fork Truck Performance"!

NOTES

ANALYSIS OF MATERIAL MOVEMENT WITH TRAVEL CHARTS

Leonard C. Schmidt
Works Manager
Worcester Pressed Steel Company
Worcester 6, Massachusetts

The degree of efficiency that is reached in the use of manufacturing facilities is frequently determined by the factory layout. A layout which necessitates an excessive handling of material invariably will increase the cost of manufacturing a product.

The optimum arrangement of factory equipment and the use of floor space is difficult to visualize regardless of whether the problem concerns the layout of a new plant or the re-arranging of existing manufacturing facilities. Line flow charts are usually used to chart material movement but this method does not show the degree of dependency of one area upon another and neither does it provide a means of weighting equipment utilization and material movement.

Travel charts provide information that is now shown by the conventional line flow chart. The travel chart method of analyzing material movement, in addition to showing the areas in which material is produced and the areas in which it is used, also shows the degree of self-sufficiency of product lines and also the degree to which a contributing area supports various product lines.

The travel chart has proved to be a very useful tool not only for analyzing manufacturing problems, but also for coordinating manufacturing plans with engineering and sales activities.

Since design engineers can have a strong influence on the creation and solution of material-handling problems, it seems quite proper that a "Materials Handling Conference" should include a note on this phase. Product design may be the deciding factor in the selection of packaging and material-handling equipment. For example, the need for holding close tolerances on delicate and intricate parts may dictate the use of special and sometimes expensive material-handling facilities. Special materials may require an unusual factory process which necessitates the purchase of special handling equipment. The weight or volume of a product frequently determines not only the manufacturing facilities required, but also the facilities required to move the material into and out of manufacturing areas.

These, and many other factors which are under the control of the design engineer, can either simplify or complicate the

material-handling engineer's job. Therefore, the design engineer should have a clear understanding of material-handling techniques.

The general subject of material handling can be divided into four parts, each providing opportunity for cost reduction and optimum use of material-handling techniques:

1. Movement of material from sources of supply to the factory.
2. Movement of materials within factories during the manufacturing process.
3. Movement of material and manufactured goods between factories and buildings for additional processing.
4. Movement of goods to distributors or ultimate consumers.

When a new plant location is being considered, or when a search is being made for new sources of material supply, the industrial engineer must give careful consideration to the cost of moving materials falling under 1 and 4. After the source of material has been selected, and the plant has been built, the responsibility for reducing the cost of materials falling under 1 and 4 lies largely in the hands of purchasing, traffic, and marketing functions. Material-handling conditions in 1 and 4 cannot be changed with the same degree of freedom that is present in 2 and 3. Within the manufacturing process, the industrial engineer can make a substantial contribution to the reduction of manufacturing cost and the shortening of manufacturing cycles. For this reason, the remainder of this paper will be devoted to the analysis of movement of materials within factories during manufacturing processes and the opportunities that lie in this area for the improvement of plant layouts.

Movement of Materials within Factories

Unnecessary movement of material is an economic waste and its elimination deserves the attention of top management. It is an element of manufacturing cost which adds nothing to the value of a product. Furthermore, it increases work-in-process inventory, losses due to damage in handling, and capital investment for material handling equipment and storage facilities.

It has been estimated by material handling authorities that approximately 70% of the nation's workers are engaged in the transportation and handling of material. Such a use of manpower represents a challenge to industrial engineers who can minimize or eliminate material handling and release manpower and energy for more useful purposes.

A starting point for the reduction of material handling is in the factory layout. An efficient layout will reduce material handling to a minimum and will permit the most efficient utilization of floor space and facilities. In order to find the best

layout of a factory and the most efficient use of manufacturing facilities, an analysis of material flow should first be made. The pattern of material flow should be clearly understood by the layout engineers before they attempt to locate machinery and other factory equipment. Because this phase of making a layout was not given proper consideration, many factories are burdened with needless material movement and complicated production control routines. Mistakes made during the plant layout stage which result in high material-handling costs can only be rectified by expensive rearrangements of manufacturing facilities.

One reason for poor plant layouts is the difficulty of visualizing and clarifying complex inter-department, inter-building, or inter-factory material movements. In order to provide necessary information in a clear and understandable form, travel charts have been developed which, although apparently little known, are proving to be a useful means for analyzing material handling problems. Material handling engineers find them useful in presenting a dramatic and easily understood picture to top management.

Travel Charts

Travel charts help to plan new material travel routes or to illustrate existing routes. In addition to showing material movement between areas or between machines, they show the self-sufficiency of manufacturing areas as well as the dependency of a manufacturing area upon other areas which contribute to it. The travel chart also shows the end use of a product and calls attention to inventory control problems resulting from complex material movement patterns.

The conventional method of analyzing material flow is to show route lines on a chart connecting the areas through which the material passes. This is a simple chart when only a single product is involved but, as the number of material items increases, and the directions of travel multiply, such a chart eventually becomes a maze of lines which are meaningless to anyone except the person who made it.

Figure (1) illustrates the method of showing material flow by flow lines for a single product. This flow plan is easily followed and analyzed, particularly when few areas and parts are involved.

Figure (2) illustrates the difficulty of analyzing material movement by the use of flow lines for multiple product flow. A single chart has now become a maze of lines which makes it very difficult to locate waste motion. This method of charting material movement provides no convenient way of evaluating the amount of material that is moved between particular areas, and

neither does it show the dependency of one area upon another. Furthermore, this method is time consuming, since each line must be individually traced and each path must be individually studied. Even after careful study of this chart, the user is still unable to visualize at a glance all of the possible combinations of movement that may take place between the areas being studied.

How to Make A Travel Chart

Instead of using the complex method illustrated by Figures 1 and 2, a simple way of showing not only the same information but other important information is afforded by a travel chart. Such a chart can be built to analyze material movement between buildings or between manufacturing areas within a single building or between machines within a single manufacturing area. The techniques involved are the same regardless of the material or the material handling problem that is being studied.

Figure (3) shows the method of building a chart. The areas on the horizontal axis are shown as suppliers or contributors, and those on the vertical axis as receivers or users. In the illustration shown by Figure 3, a hypothetical set of conditions has been selected. This illustration can be applied to machines or areas located in two buildings, A and B. The horizontal numbers can be either areas or machines and the same is true of the vertical numbers.

First, the areas or machines are listed in numerical order from one to ten across the top of the chart. Next, the areas or machines are listed down the left-hand side of the chart in exactly the same order. It is now necessary to measure the output of the contributors in some convenient manner. When multiple products are being produced by a contributor, it has been found most convenient to use direct labor content of a product since this is a measure of the time required to produce a unit of the product. Manufacturing time is the only common denominator that can be applied to a multiplicity of products. By the use of planning cards, operation sequence sheets, time studies, or labor vouchers, it is possible to determine the amount of direct labor or time that is used in each of the contributing areas to produce material for the users listed on the lefthand side of the chart. Figure 3, shows the percent of the output of each contributor that goes to each user.

Since it is quite possible that some of the output of the contributing areas is not sent to a user area, but instead is shipped directly to customers, there should be included across the bottom of the chart a table showing the percent of time or labor that is used to produce this portion of the output.

The numbers in the vertical columns under each of the con-

tributors, including those numbers listed opposite "customer," must total 100%. This accounts for the entire output of each of the contributors. The numbers opposite each of the users which are listed on the left-hand side of the chart show the percent of the contributors' output that is taken by each user.

How to Use a Travel Chart

An examination of Figure 3 immediately discloses that the conditions shown by this chart represent an improper arrangement. For example, 100% of the output of contributor 5 goes to user 8; however, contributor 5 is in building (A) while user 8 is in building (B). It is evident then that contributor 5 and user 8 should be brought together in one building and in areas that are adjacent to each other.

Sixty percent of the output of contributor 1 is used in building (A), and 40% is used in building (B). That portion of the output of contributor 1 that is used in building (A) is distributed between users 2, 3, and 4, and that portion which is used in building (B) is distributed between users 7, 8, and 10. This distribution of contributor 1's output indicates that contributor 1 is making a standard type of product which finds use in many areas of the factory or it may indicate that contributor 1's area is equipped with standard type of machines which are making parts suitable for many products. The distribution of the output of contributor 1 shows that it makes little difference whether contributor 1 is located in building (A) or building (B) since there will be approximately an equal amount of material movement in either case. The chart does show, however, that contributor 1 should be divided between building (A) and building (B) if the savings to be realized from a reduction of material movement will justify duplicate facilities in each building.

An analysis of the output of contributor 9 shows that this contributor can be located in either building (A) or building (B) since its entire output goes direct to customers. A location as close to the shipping areas as possible should be selected for this contributor.

The output of the remainder of the contributors can be examined in a similar manner and the proper location for each contributor with respect to the user areas can be determined.

To simplify the examination of the chart, chimneys can be constructed which show the end use of the contributors' output. The chimneys at the bottom of Figure 3 show extremely bad conditions since only a small percentage of the output of the contributors finds its end use in the building in which the contributor is located.

On the right-hand side of Figure 3 has been constructed two columns of figures showing the percent self-supporting within the building and the percent contributed from other sources. It should be explained that the numbers opposite each user do not add to 100%. These numbers show only the dependency of each user upon the output of the contributor. To determine the degree to which a product line is "self-supporting," an analysis of the total direct labor of that product line must be made. That portion of the product direct labor that is performed by contributors is then calculated. The ratio between direct labor performed by the product line area and the direct labor performed by the contributors is shown in the two right-hand columns. The bar chart on the far right of Figure 3 shows graphically the degree to which each product line is self-supporting.

Using the information that is provided by the travel chart shown in Figure 3, it is possible to re-arrange contributors and users into a pattern such as that shown by Figure 4.

Contributors 1, 3, 5, and 8 have now been located in building (A) while contributors 2, 4, 6, 7, 9, and 10 have been located in building (B). The significance of the gains that have been made in the reduction of material movement is shown by the chimney chart at the bottom of Figure 4. By comparing this chimney chart with the one shown in Figure 3, it will be seen that the end use of the output of the contributing areas within the building in which they are located has been substantially improved. It should be noted that the largest numbers on the charts (those which approach 100%) are now grouped in building (A) and building (B). This indicates that the end use of the contributors' output is confined largely to the buildings in which the contributors are located.

Another indication of a betterment of conditions is the degree to which the numbers can be located close to a 45 degree diagonal. The nearer the numbers on this chart can be aligned with the 45 degree diagonal, the more self-sufficient will be the user area. For example, if all the numbers fell on a 45 degree line, all users would be self-supporting as far as output of contributing areas is concerned and this would represent ideal conditions from the standpoint of material handling. Such an arrangement would denote unit setups and that all material manufactured in a specific area is used in that area and that this area would depend upon no other, and would ship to no other. Thus inter-area travel would be at a minimum.

Figure (5) shows what can be done by carrying the re-arrangement to a higher degree. Figures 3 and 4 showed that contributors 1 and 2 furnished material to buildings (A) and (B). The facilities of these two areas can be divided between these buildings so

that (A) will contain contributors and users 1, 2, 3, 5, and 8 while building (B) will contain newly created contributors and uses (1A) and (2A) and also contributors and users 4, 6, 7, 9, and 10. With this arrangement, an almost ideal set of conditions, insofar as elimination of material movement between buildings is concerned, has been achieved. Building (A) is now dependent upon building (B) for only 5% of the output of contributor 10. Building (B) is dependent upon (A) for 15% of the output of contributor 3 and 10% of the output of contributor 8. This is the only material that is moved between the two buildings.

The improved conditions are illustrated graphically by chimneys at the bottom of Figure 5 which show a high degree of end use of the material within the area in which it is produced and a high degree of self-sufficiency of the product lines.

In using the travel chart, it is very important to keep in mind that an analysis is being made of the proper location of machines or areas in which direct labor is being expended on parts which may be used in another area. The primary objective of the travel chart method of analyzing material movement is to determine the proper location of contributing areas and machines so that, whenever the economics involved show justification, contributor and user areas can be so combined that products produced in an area can be used within that area. It is not necessary to include in the travel chart material purchases from outside sources on which contributing labor is performed since this material can be sent directly to the user area.

Case Studies - Use of a Travel Chart

Figures 6 and 7 show an actual study that was made. Figure 6 shows the conditions as they were found to exist. The areas shown as A, D, B, and C happen to be areas of supervisory responsibility. The areas making up the main supervisory areas, namely A, D, B, and C, were grouped because of the similarity of products which were produced in them. The travel chart shows that (A) is located entirely in one multi-story building. Area (D) likewise is located in one multi-story building. Area (B) is made up of areas which are located in five buildings. Area (C) is most fortunate since it is located in just one single-story building.

The travel chart was constructed as explained by illustrations in Figures 3, 4, and 5. The contributor sections are shown across the top and the users down the left-hand side. All of the numbers that fall outside of areas A, D, B, and C show the dependency of the user sections upon the contributing sections. It is evident that the chart represents very poor conditions, and

also illustrates the tremendous amount of material movement and complex production and inventory control problems that must exist. Only a remarkably strong production organization with complete scheduling and dispatch system could possibly cope with this situation in a satisfactory and economical manner.

The conditions shown in Figure 6 were permitted to develop over a period of time in which no coordinated plan to provide for the growth of this particular business had been made. As the business grew, it was found that product lines built in other plants which were located many miles removed from the parent plant should - for the purpose of creating a unified business - be located in one plant. Eventually such a combination of product lines was made in one locality. This was done, however, without a clear conception of the inter-relationship of the products, and the complex production control and material movement situations that were being created. In other words, no analysis was made before physical layouts were started. It has now become necessary to spend large sums of money to correct existing conditions and to provide for an increased output from the same manufacturing area.

Many attempts were made to correct the conditions in Figure 6 in the conventional manner of making two- and three-dimensional layouts. Each time such a layout was made, complications arose due to lack of knowledge of the proper relationship between machining areas and assembly areas, and between one machining area and all other machining areas. In order to provide required information for the construction of three-dimensional layouts, the travel chart was used. The conditions disclosed by Figure 6 were both startling and informative. It was immediately evident that certain contributing sections should be located with certain user sections and it was also evident that the contributing sections should be broken up and divided between several users.

When consideration was given to the proper family relationship of the product lines, it became evident that areas had been assigned to product lines which were too large in some cases and too small in others. After the best arrangement had been determined, including the size of each area, it was found that some product lines had to be assigned to different buildings.

Figure (7) shows the travel chart which resulted from an analysis of the chart shown in Figure 6. By reassigning buildings and areas within buildings, it is now possible to combine product lines into families and to provide for high percentage end-use of section output in the buildings in which the sections are located. Some of the contributing sections have been broken up and located with their related product lines. For example, there are four coil contributing sections instead of two. There are now two

sheet-metal shops instead of one. Contributing sections which make renewal parts and parts for warehouse stock have been located in the warehouse building.

The areas analyzed by Figures 6 and 7 comprise about 1,500,000 sq. ft. of manufacturing space. Figure 7 has become the pattern for long-range re-arrangement programs. It was an important tool in the hands of management when plans were formulated for the spending of money to modernize manufacturing facilities. It is proving to be an important tool for the determination of the proper location of new product lines so that they will be integrated with the long-range modernization program. As a by-product of the study, the output per square foot of floor space has been materially increased, thereby increasing the output capacity by 25%.

Additional Uses of the Travel Chart

The travel chart in the particular instance just cited has been found useful for making overall studies of the proper family relationship between products within this particular manufacturing department and products that are manufactured by other departments. It has been used to study the proper relationship of products manufactured in two different plants and, in some cases, this has resulted in the transfer of products between plants and departments.

Information provided by the travel chart has been used to determine the size of manufacturing areas and the structural features of buildings in which certain products are to be manufactured. It has also been used to orient the manufacturing facilities of one department with the needs of other departments located in the same multi-product plant.

After an analysis of the travel chart has been completed, the next step is to prepare two-dimensional or three-dimensional layouts of the manufacturing areas. The three-dimensional layout shown in Figure 8 is a product of Figure 7. This is a layout of a portion of area C. As a result of this layout and the analysis of travel charts, orders have been placed for machinery and new facilities which will substantially reduce manufacturing cost and simplify the movement of material. This layout was then expanded to include all of area C, and the remaining areas.

In addition to those uses for a travel chart which have already been discussed, it can be used to provide other information. The travel chart's primary function is to provide the layout engineer with an analysis of material movement problems

so that he can readily determine the best physical relationship of areas and machines and provide proper material-handling facilities. These facilities may consist of short conveyors which link several operations into a progressive manufacturing operation. They may consist of manually or power-operated trucks, or they may consist of intricate conveyor systems that link areas of a building together in a pattern best suited to the manufacture of particular products. Any arrangement which reduces material handling and integrates manufacturing operations into a co-ordinated pattern will simplify production control and improve work-in-process inventory turnover.

In order to reach the optimum arrangement of manufacturing facilities, it is quite possible that products will be arranged in a pattern differing from engineering and sales organizational patterns. In some cases, this will lead to better coordination between manufacturing, engineering, and sales functions which will simplify the entire management structure. To reap the greatest benefit from the use of travel charts, the engineering and sales functions should be acquainted with them and their interpretation, and also with the importance of making the most economical use of manufacturing floor space and equipment.

If a factory has not been modernized for several years, it is not unusual to find that product lines have lost their family relationship and have become a jumble of model numbers and forms, some of which are quite unrelated to other products built in the same area or in the same building. Manufacturing and production control techniques, which should be segregated in accordance with product line requirements, then become a mixture of job shop and mass production procedures. Under such conditions, the factory organization cannot make the most effective use of modern techniques for the building of better products in less time and at lower cost.

When preparing a travel chart, it will be found advantageous, and in some cases absolutely necessary, to make engineering a party to the study so that product lines can be simplified and standardized in order to permit the use of new methods and improved facilities.

Simplification and standardization of product lines is one of the most important benefits to be derived from travel chart analysis. Furthermore, it is an approach to the solution of manufacturing problems which is appreciated by the engineering profession. The common interests which are developed by the travel chart method of analyzing manufacturing problems results in enthusiastic cooperation between functions.

A long-range plan such as that outlined by Figure 7 provides

not only industrial engineers but also top management with a means of coordinating plans for product design with plans for improved factory facilities. Savings from such coordination, in addition to those which can be made by reduced material handling and work-in-process inventory, will often pay for re-arrangement and new equipment over a period of a very few years.

With the adoption of a long-range facilities plan, engineering and sales activities can be coordinated with manufacturing plans. Participation of all supervisors in the development of these plans usually provides a stimulation to the entire organization which makes them enthusiastic supporters of the program. Frequently these supervisors will contribute many worthwhile ideas as a result of their participation in the planning study.

Summary

The purpose, construction, and use of a travel chart can be summarized as follows:

1. The purpose of the travel chart is to provide a simple method of analyzing complex material movement with the objective in mind of making more efficient use of manufacturing facilities.

2. The principle of the travel chart is the same as that used on mileage charts on the back of road maps to show the distance between cities.
By listing manufacturing areas across the top of the chart as contributors and down the left-hand side as users, it is possible to show the dependency of one area upon the other area. From the data obtained in this manner, the proper location of manufacturing facilities in order to reduce material movement distances can be determined.

3. As contrasted to the usual flow-line method of charting material flow, the travel chart provides a means of measuring the utilization of facilities to produce material for each of the user areas.

4. From a travel chart showing material movement after the proposed re-arrangement, industrial engineers can determine the optimum arrangement of facilities to achieve the highest possible degree of product line self-sufficiency.

5. After the proposed re-arrangement plan has been selected, a two-dimensional or three-dimensional layout can be made for proper assignment of areas and facilities to contributors and users.

6. An analytical approach to the solution of manufacturing problems will assist in establishing proper relationship between engineering, sales, and manufacturing functions.

7. After the selection of a long-range facilities program and coordination of this program with engineering and sales facilities, management is in a position to program the expansion or re-arrangement of facilities and the putting into production of new product lines.

8. Because the travel chart facilitates the making of detailed studies of many important management problems, it is strongly recommended as a management tool for analyzing existing manufacturing facilities and for the planning of new facilities.

Paper Presented -

American Institute of Industrial Engineers
St. Louis, Missouri

May 1955

CAPTIONS

Figure 1 Flow plan for a single product. Easy enough to follow where few parts are involved.

Figure 2 Flow plan for multiple products. Flow lines become a maze of lines which are difficult to study and evaluate for needless material movement.

Figure 3 A simple form of travel chart. Contributors 1 - 10 arranged across the top of the chart and uses 1 - 10 arranged on the left-hand side of the chart. The numbers in the squares show the percent of the contributors' facilities that are used to manufacture material for the users.

Figure 4 The contributors and users shown in Figure 3 have been re-arranged to provide greater self-sufficiency in the user areas and greater end use of material in the building in which it is manufactured.

Figure 5 By dividing the facilities of contributors 1 and 2 between buildings A and B, material movement between the buildings has been reduced. This results in a greater usage of material within the building in which it is manufactured and the product lines are self-supporting to a higher degree.

Figure 6 This chart shows existing conditions in a case study. Note that end usage of material within the manufacturing building is low and self-supporting of product lines is also relatively low.

Figure 7 This chart shows proposed re-arrangement of facilities to improve conditions shown by Figure 6. Note a higher end use of material within the manufacturing building and also a substantial improvement in the degree to which the product line is self-supporting.

Figure 8 Three-dimensional layout of part of area C shown in Figure 7. This arrangement is a product of the travel chart analysis and substantially reduces movement of material and work-in-process inventory.

SINGLE PRODUCT FLOW

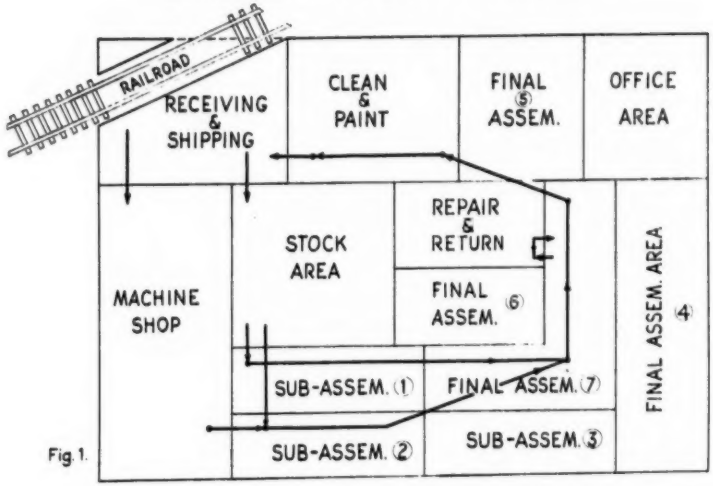


Fig. 1.

MULTIPLE PRODUCT FLOW

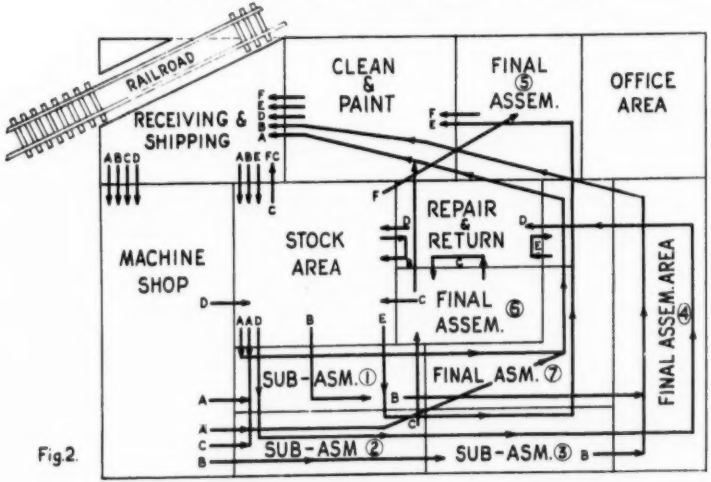


Fig.2.

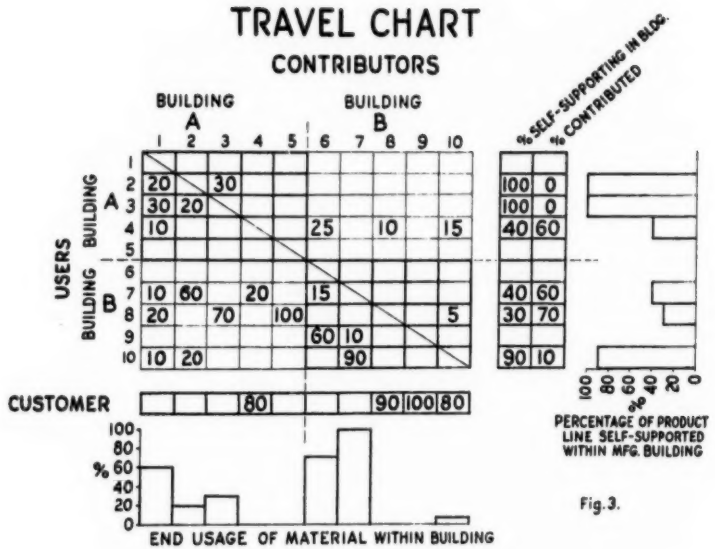

TRAVEL CHART
CONTRIBUTORS
BUILDING A
BUILDING B
1 2 3 4 5 6 7 8 9 10
USERS
BUILDING A
BUILDING B
1 2 3 4 5 6 7 8 9 10
20 30
30 20
10 25 10 15
10 60 20 15
20 70 100 5
60 10
10 20 90
CUSTOMER
80 90 100 80
100 80 60 40 20 0
%
END USAGE OF MATERIAL WITHIN BUILDING
% SELF-SUPPORTING IN BLDG.
% CONTRIBUTED
100 0
100 0
40 60
40 60
30 70
90 10
100 80 60 40 20 0
%
PERCENTAGE OF PRODUCT LINE SELF-SUPPORTED WITHIN MFG. BUILDING

Fig. 3.

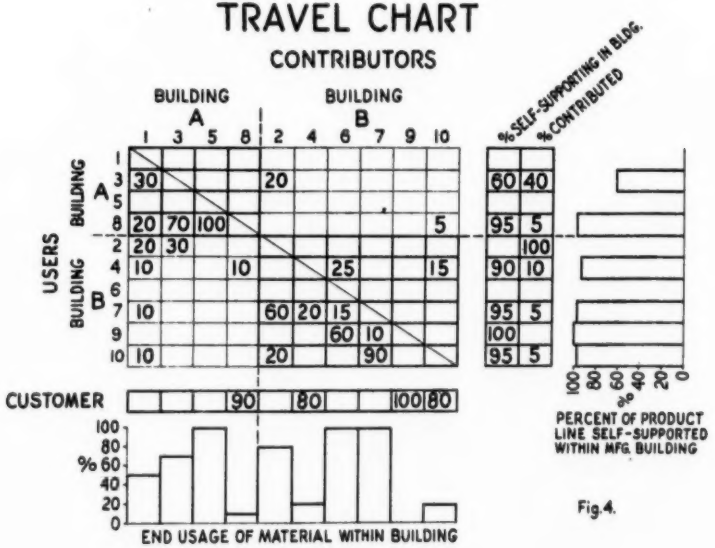

TRAVEL CHART
CONTRIBUTORS
BUILDING A
BUILDING B
1 3 5 8 2 4 6 7 9 10
USERS
BUILDING A
BUILDING B
1
3 30 20
5
8 20 70 100 5
2 20 30
4 10 10 25 15
6
7 10 60 20 15
9 60 10
10 10 20 90
CUSTOMER 90 80 100 80
% SELF-SUPPORTING IN BLDG.
% CONTRIBUTED
60 40
95 5
100
90 10
95 5
100
95 5
100 80 60 40 20 0
%
PERCENT OF PRODUCT LINE SELF-SUPPORTED WITHIN MFG. BUILDING
100 80 60 40 20 0
% 60
END USAGE OF MATERIAL WITHIN BUILDING

Fig. 4.

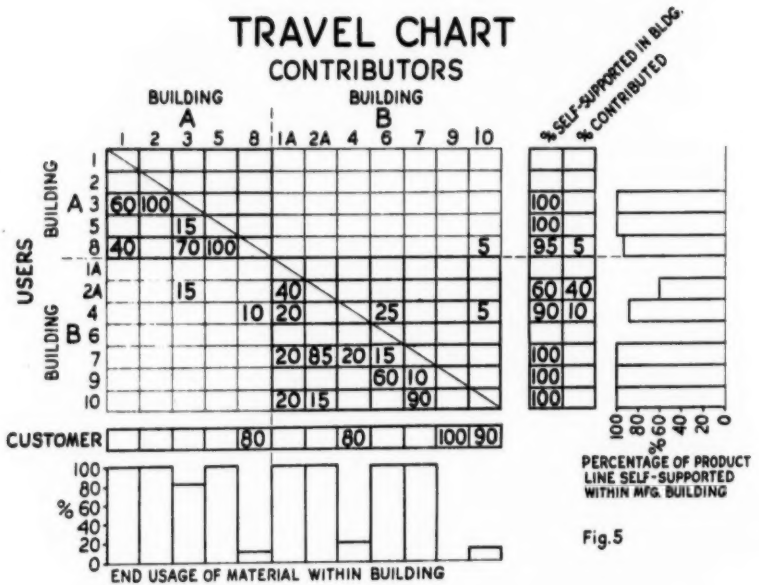

TRAVEL CHART
CONTRIBUTORS
BUILDING A
BUILDING B
1 2 3 5 8 1A 2A 4 6 7 9 10
USERS
BUILDING A
BUILDING B
1
2
A 3
5
8
1A
2A
4
B 6
7
9
10
60 100
15
40 70 100 5
15 40
10 20 25 5
20 85 20 15
60 10
20 15 90
CUSTOMER
80 80 100 90
100
80
% 60
40
20
0
END USAGE OF MATERIAL WITHIN BUILDING
% SELF-SUPPORTED IN BLDG.
% CONTRIBUTED
100 100
95 5
60 40
90 10
100
100
100
100 80 60 40 20 0
%
PERCENTAGE OF PRODUCT LINE SELF-SUPPORTED WITHIN MFG. BUILDING

Fig.5

PRESENT MANUFACTURING ARRANGEMENT

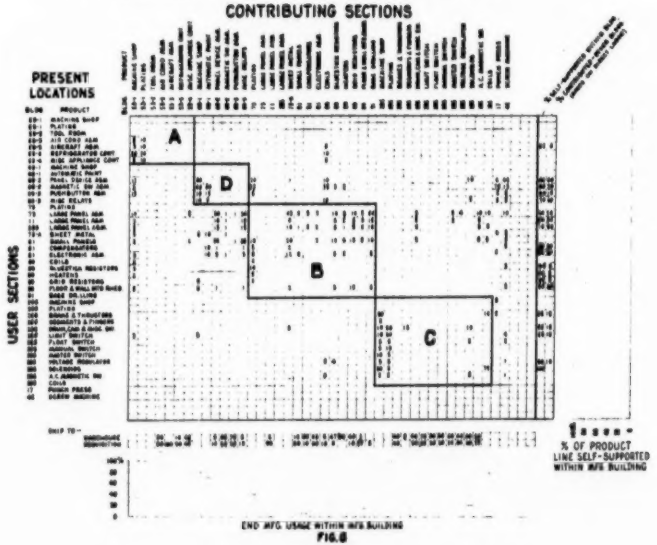


FIG. 8

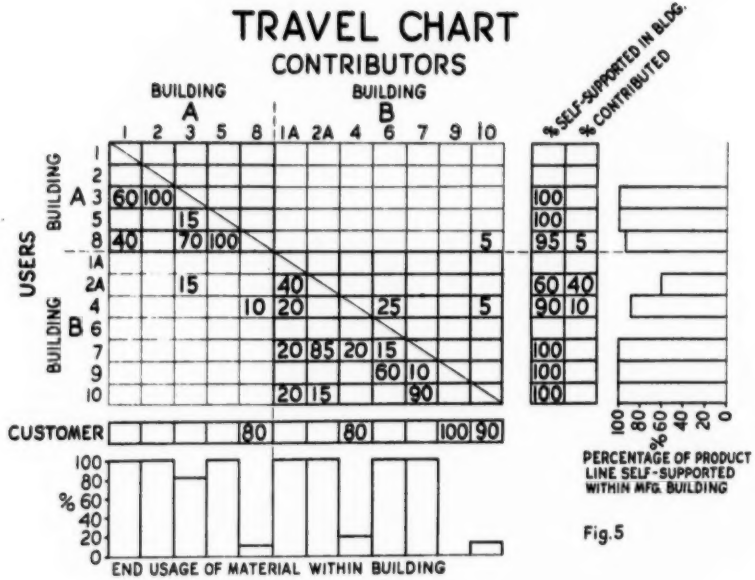

TRAVEL CHART
CONTRIBUTORS
BUILDING A
BUILDING B
1 2 3 5 8 1A 2A 4 6 7 9 10
USERS
BUILDING A
BUILDING B
1 2 3 5 8 1A 2A 4 6 7 9 10
60 100
40 70 100 5
15 40
10 20 25 5
20 85 20 15
60 10
20 15 90
CUSTOMER
80 80 100 90
% SELF-SUPPORTED IN BLDG.
% CONTRIBUTED
100 100 95 5 60 40 90 10 100 100 100
100 80 60 40 20 0
%
PERCENTAGE OF PRODUCT LINE SELF-SUPPORTED WITHIN MFG. BUILDING
100 80 60 40 20 0
%
END USAGE OF MATERIAL WITHIN BUILDING

Fig.5

PRESENT MANUFACTURING ARRANGEMENT

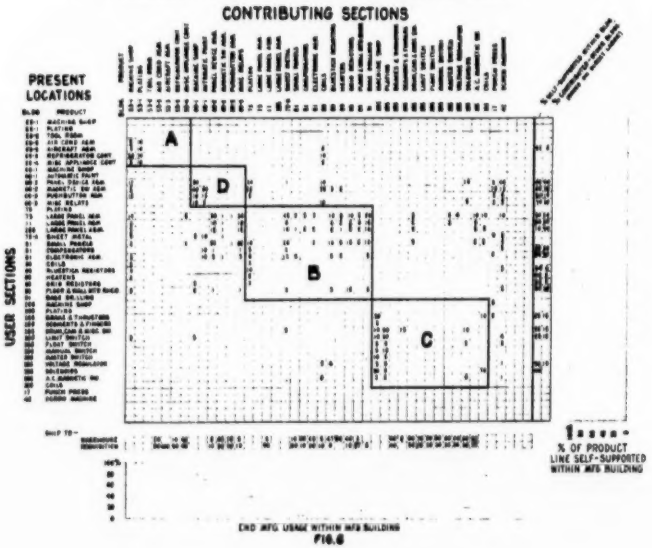


FIG. 6

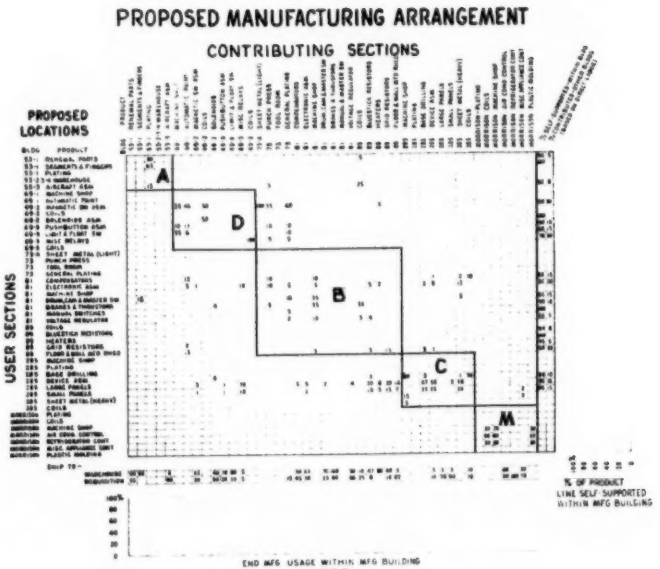

PROPOSED MANUFACTURING ARRANGEMENT
CONTRIBUTING SECTIONS
PROPOSED LOCATIONS
USER SECTIONS
A
D
B
C
M
% OF PRODUCT LINE SELF-SUPPORTED WITHIN MFG BUILDING
END MFG USAGE WITHIN MFG BUILDING

FIG.7

NOTES

RESEARCH IN PLANT LAYOUT AND MATERIAL HANDLING

by

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Los Angeles

It was only eight or ten years ago that industry, and the Armed Forces, really recognized the potential time and money savings possible through improvements in plant layout and handling methods--and packaging. Their attempts to obtain these savings underlined the needs for analysis techniques, facts and suitable equipment to make the improvements. These needs accelerated research in the equipment design being conducted by manufacturers; they sparked a rapid growth of independent investigations, particularly into industrial material handling problems.

I shall talk today primarily about the latter studies--not because equipment development is minor or unimportant; it is far from that. But equipment research results are, sooner or later, widely disseminated through trade journals. Packaging research is a complete topic in itself, and should be discussed at another time. My discussion of independent research in layout and handling will consider three major categories and present conclusions and recommendations. These topics are:

a. Investigations of material movement or "flow"
b. Other studies in plant layout and warehousing
c. Handling research at the University of California, Los Angeles

RESEARCH INTO MATERIAL MOVEMENT OR "FLOW"

Intermittent Flow--A substantial portion of all plant layout and material handling research has dealt with the "flow" of materials and the cost of that movement in manufacturing plants--particularly job-lot plants--and warehouses. One of the first to consider this problem was Jack Freeman (1)* who, in 1947, developed a variation of the "travel chart" which D. G. Cameron has described (2) and which L. G. Schmidt discussed at this Convention yesterday (3). In 1950 and 1951, S. P. Gantz (4) and R. B. Pettit (5) used the distance material travels as one index of handling cost for evaluating alternate layouts. Suspecting this particular premise, in 1953 I investigated the relationship (6) between cost and distance while a member of the Management Sciences Research Project at the University of California, Los Angeles. My investigations led to the conclusion that the two are not directly proportional because the handler and his equipment are not in motion a major portion of the working shift. In many plants 50% and more of the time is either invested to picking-up and putting-down loads or wasted because the equipment is idle or delayed; the costs of these two components are not related to movement distance. Recognition of these facts is evident in a very recent article (7) showing how linear programming will indicate the best layout "if total distance represents, to any degree, a measure of value of alternate layouts." To ascertain fully the relationship between distance and handling cost, much more research is needed.

* Numbers in parentheses refer to references listed at the end of this paper.

Industrial Truck Operating Times--A growing desire to control the cost of moving materials in job-lot plants and warehouses, together with application of the time-lapse camera (8, 9) to handling research, has led to widespread study of fork truck operating times. About 18 months ago four universities--the Georgia School of Technology, Purdue University, the University of Pennsylvania, and the University of Southern California--were studying various aspects of fork truck operating times with time-lapse cameras. The most extensive studies, conducted at the University of Pennsylvania (10ab), and those at Georgia Tech (11), resulted in standard data for specific capacity gas and electric fork trucks. The University of Southern California studies (12, 13) indicated that differences in driver skill can produce 20 to 30% differences in times for a given operation. The Purdue research (14) found that the number of stops, the type of aisle and the distance traveled were other parameters that affected fork truck trip time significantly.

The Department of Agriculture has conducted investigations into the method and cost of moving materials in produce warehouses (15), in cotton gins and warehouses (16) and in the apple industry (17). Almost all of these studies have generated standard data for fork and hand trucks; many have converted these data into costs. The apple research is particularly outstanding; those who don't have time to read the reports of this project should see the film, "Apple Handling"

Despite careful work, many of the truck time studies have not established all the desired or necessary data; others, instead of being conclusive, have shown new areas needing investigation. Since warehouse and factory managers are more interested than ever in controlling handling costs, study of operating times for all kinds of industrial trucks should continue.

Rolling Resistance--The increased use of hand trucks has made a recently reported study (18) of rolling resistance very timely. The research results quantify the well known fact that the force required to move a wheeled vehicle is inversely proportional to the diameter of the wheels used; the results show, as energy considerations would predict, that the proportionality constant is greatest for rubber-tired wheels; they also show that rubber-tired wheels are no harder to start than steel or other hard wheels when the floor is littered or rough, and that there is much variability in force required to start supposedly equivalent wheels. Variability of this sort indicates the desirability of more research.

Continuous Flow--While P. G. Moore has studied the in-process inventory of mass production plants (19) and others have investigated other phases of continuous flow, most research into this subject, and automation, has been and is being conducted by equipment manufacturers and users in conjunction with design problems. Typical of this work are the studies which have developed the conveyers that may replace escalaters and present-day subways (20) and even railroads (21). Some independent studies have also been performed at the University of Michigan and Michigan State College.

Recently J. K. Rudd (22), A. W. Jenike (23) and John Reese (24) have begun quantitative investigations of the mechanisms underlying the flow of material from storage bins. From their work may come bin design data which will reduce material "arching" and thus eliminate the hammering--or its sophisticated equivalent, the mechanical vibration of the bin--to induce flow. Since most bulk material handling and current automation techniques are primarily empirical, it appears that there are many opportunities for research in both these areas.

Material Movement Outside of Plants and Warehouses--In addition to the investigations of flow in factories and warehouses, there have been studies of the movement of material in many other environments. Investigations by the Armed Forces, for example, have dealt with the flow of materials from the production line to the battle line (25, 26), with the specific problems of air and ocean cargo movement (26, 27, 28), and with such details as inflatable dunnage, car loading, and equipment life (29). Other groups are known to be investigating the handling of air line baggage and many other problems of interest to specific groups and too numerous to report here.

Other Research in Layout and Warehousing--There has been relatively little formal research into aspects of layout and warehousing other than material flow. S. P. Gantz (4) and Pettit (5) established criteria other than flow for evaluating alternate layouts; but they treated various criteria as separate entities with equal weight. On the basis of his experience, Richard Muther (30) proposes a weighting scheme for evaluating layouts; M. F. Shakun (31) has presented a theoretical, mathematical approach which seeks to evaluate the effect of layout changes on costs. But no one has produced a generally accepted procedure for evaluating alternate layouts. Perhaps the basis of evaluation is so specific to each layout that no one procedure can suffice. To prove or disprove this, more research is needed, again.

While the American Trucking Association and others have sponsored studies (32) into such warehousing layout problems as space utilization, most of the research has been conducted by the Department of Agriculture and the Armed Forces. The results of this work are spelled out in the Department of Agriculture reports (15, 16, 17), the new Navy Handbook (33) and in articles that appear in various trade journals (34 for example). Generally speaking though, practically all research into layout problems other than flow in factories and warehouses remains to be done.

MATERIAL HANDLING RESEARCH AT THE UNIVERSITY OF CALIFORNIA, LOS ANGELES

Current research at the University of California, Los Angeles, is investigating two handling problems: the loading and unloading of ships, or "cargo handling," and the handling--and packaging--of citrus fruit.

Cargo Handling Research--The Cargo Handling Research Project has been conducted for the past three years by the Department of Engineering with the active support and financial assistance of the Office of Naval Research and Maritime Administration. This project has been concerned primarily with the movement of commodities between land carriers and ocean-going vessels (27).

Ship loading activities have been viewed as a series of cyclic operations, called "links," in each of which a handling device moves a load (or commodity) from storage point "a" to storage point "b" and then returns to "a" to repeat the cycle. All links are similar in that each requires repeated round trips by the handling device, or transporting agent, and each includes pick-up, transport loaded, release, transport empty, and delay elements. Delays associated with performance of the link (such as stopping to replace boxes dropped from a unit load in transit) are called "internal" delays; delays to a link resulting from non-performance of preceding or following links are called "induced delays."

Preliminary studies of ship loading operations were the basis for two hypotheses:

1. If there is a group of transporting links connected in series, then there is one link which has the least mean induced delay and which controls the speed of the entire loading operation.

2. The relationship between the relevant factors which affect the delay time for a link can be so formulated that delay time can be predicted.

Both of these hypotheses were investigated during a field study of the wharf, hook, and hold links required to move cargo from its point of rest on the dock to the stowed position in the ship's hold.

Work sampling was used to obtain data which partially verified the first hypothesis. In 43 of the studies, the "slowest" and controlling link was the hook link, in 23 of them it was the hold link, and in 16 it was the wharf link. Since the data were highly variable, a complete analysis of the effects of cycle-to-cycle variability is currently under consideration. Russell R. O'Neill, Project Leader, currently is preparing the data for computations utilizing SWAC--computations which will test the interactions between links.

The Cargo Handling Project is of special interest because it has employed a research team consisting of personnel from various fields of engineering and psychology and because it has utilized the mode of analysis which Mr. Boelter will discuss later this morning. Many of you who are familiar with servo-mechanism analogies to production control systems will be interested in the electrical circuit analogy to ship loading which this team has developed.

Citrus Fruit Packaging and Handling Research--The second active handling research project has been conducted by the Departments of Agricultural Economics and Agricultural Engineering (at Davis) with the assistance of the Departments of Engineering at Los Angeles and Berkeley since 1947. This project, sponsored by the Citrus Industry Research Association, has investigated such problems as: the replacement of individual field boxes* with bulk containers; the efficient handling of these containers in the orchard, to and at the packing house (35); conveyorization of the packing operation, and the development of grading chutes (36). Initial work on the last project was performed on the Berkeley campus.

Professor Roy Smith, who has directed this research, is particularly proud of two results (37). The first of these is the replacement of the wooden crate by a corrugated fibreboard carton; the second is the replacement of the laborious hand wrapping of fruit and manual packing in the shipping container by a simple mechanical system which pours the fruit into the container and vibrates it as necessary to obtain a solid pack. These two changes alone have saved the lemon growers of California about $3,000,000 per year and promise to save three or four times that much when adopted by the orange growers.

The Citrus research is a good example of research that has dealt with handling and packaging as interrelated problems. For example, to develop the new container and packaging method and then to "sell" it to all concerned required the efforts of agricultural economists, engineers of all types, plant physiologists

* These are boxes about the size of the wooden orange crate of the past but constructed of heavier lumber to protect the fruit during field handling and storage in the packing house.

and pathologists, and chemists. The interrelationship of packaging and handling and the sciences, and the value of the team approach in solving such problems, needs to be emphasized again, and again, and again.

CONCLUSIONS AND SUGGESTIONS

I hope you have been impressed by two implications of this brief report on material handling research:

1. A tremendous amount of research remains to be done.

2. Most of the investigations have been "applied" research aimed at solving specific problems; relatively little theoretical research has been attempted.

Needed Research--Material handling research, in spite of its growth in the past six or eight years, has just begun. Additional investigations are needed in all the areas I have discussed and as a basis for the handling equipment standards which now are projected. Much of this further research must be empirical and "practical;" industry needs answers to everyday operating problems. On the other hand, additional theoretical consideration of such subjects as flow is worthwhile. The mathematicians have started this work (38), but the broadest generalization of the subject has been postulated by Dean Boelter, who speaks of the "theory of flow of discrete particles." To him a "discrete particle" could be a totepan carried by a man, a unit load on a fork truck, an automobile or truck in a traffic stream, or an ocean-going vessel. He reasons that there is a well defined body of knowledge and theory relative to fluid flow and that similar knowledge and theory of particle flow should be possible. Such a general theory may be possible. After all, order pickers in warehouses, fork trucks, motor trucks, and ocean-going vessels all have one characteristic in common--loading, unloading and delay time accounts for 40 to 60% of the available operating time.

On the other hand, time may not be the key variable of flow; perhaps it is the type and amount of energy expended, or the rate of its expenditure. Here again is a question that can not be answered now. Again it is apparent that handling research has grown, but much remains to be done.

Acknowledgement--The authors wish to acknowledge the assistance of Mr. Robert R. Lippert, U. S. Army; Mr. J. K. Rudd of the Richardson Scale Company; and Professors Roy Smith and Raymond Perry, and Robert Fulton of the Citrus Research Project; all of them supplied information included in this paper.

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NOTES

AUTOMATION -ENGINEERING ASPECTS

By Charles F. Hautau, Chief Design Engineer - Hautau Engineering Company

Automation is inevitable for four main reasons:

1. All patents issued prior to 1937 have now expired. Today patent emphasis is on methods of manufacture. The lifeblood of competition, therefore, will be low-cost manufacturing methods - not the product.

2. Second reason is survival. The companies in each industry that can cut costs drastically by automating will be the companies to survive. Suppose you supply parts to a customer that is automating. If you don't adopt automation, and your customer can, you'll lose your job as a supplier. I know that has already happened to at least two automotive suppliers.

3. Want another survival angle? Assume you possess years of tradition, a good fixed product design, plenty of know-how, a "modern" new plant. So what? You're stuck because a company without all your know-how and equipment will set up an automation line to build a redesigned product, and wipe you out on the basis of his low price. He won't have the handicap you have.

4. Competition from low-cost labor in foreign countries. Look at our bicycle industry. It has already lost half of it's domestic market to foreign competition.

   Automation is the only salvation this industry can possibly have, it alone provides a method for competing successfully with lo-cost labor.

Good Automation Design Incorporates these Factors:

1. Starts with receipt of the raw material.
2. Never lets go of a part until it's finished.
3. Avoids inter-machine storage, mechanically transfers parts in process from one operation to the next without delay.
4. Automatically gages or inspects the part after each key operation.
5. Corrects machine or process activity when the parts begin to drift from quality limits.
6. Calls for controlled cycling of individual machine or processes to result in balanced lines.
7. Requires machines that combine or reduce operations to a compact and efficient line.

AUTOMATION - ENGINEERING ASPECTS Cont'd

8. Calls for electrical control of operations. If possible, desirable, or economically feasible, a master panel should control the entire production line.
9. Integrates all assembly, finishing, and packaging operations.

One question frequently asked - "Can we automize existing production machines?"

The answer is yes. That can be done and has been done. By adding automatic loaders and unloaders, and by pulling standard machines together physically, you can get more production from many standard machines and machine tools. The aim is to eliminate handling. There's some advantage to beginning your automation this way. You can get started without too big an investment in new machines or plant, and you can also salvage your equity in existing equipment.

Start with medium-heavy high-production parts - say at a rate of 50 or more units per hour - made on standard machines. But the key is labor hours, not units; the idea is to reduce unit labor cost.

When you purchase new machines I suggest you anticipate automation. Order machines capable of full remote control - and suitable to automatic loading and unloading. Order machines with capacities far in excess of what you require now. As a matter of fact, you'd be smart to buy automation for those machines at the same time.

Product Design Changes -

Another point I wish to emphasize is that an automation engineer will inevitably stumble upon chances for spectacular saving in the product's construction. This is true because he questions every element in the design and manufacture of a product.

Often minor changes in design, not affecting the basic design, can result in substantial assembly savings by permitting use of automation.

The Qualities of a Good Automation Engineer -

Vision is most important. If a man has everything else, but hasn't the vision to see processes as they can and should be, I'd say he won't make a good automation engineer.

Here are eight further essential qualifications for an automation engineer:

1. He must be familiar with the basic operating principles of all funda-

mental types of manufacturing equipment.

2. He should recognize the untapped production potential of each machine type, including the restrictions imposed by manual operation, tooling, etc.

3. He must have a broad knowledge of electrical, hydraulic, and pneumatic mechanisms, controls, and components. Also, he must know cams and kinematics.

4. He should be intimately familiar with product design principles.

5. He should know thoroughly the characteristics of product materials.

6. He should know competitive and allied production processes.

7. He should be able to forget how things have been made in the past, and be able to contribute fresh, progressive, revolutionary process thinking.

8. He must have the ability to sell dynamic new concepts to management.

NOTES

The Guide Chart-Profile Method of Evaluation

In evaluating high level jobs it has become necessary to secure the participation and support of top and middle management. In an effort to accomplish this, a complete revision of job evaluation methods has come about and has caused the creation of the Guide Chart-Profile Method of Job Evaluation.

This method employs job to job relationship as a principal evaluating means, with all the accuracy and clarity made possible by such direct comparison. But, in addition, it employs the objectivity of defined scales, with specific description for each level of each job element.

Instead of a multiple of factors, the plan has the simplicity of only three fundamental factors. By the use of the guide chart, these three fundamental measuring elements are described in terms of their primary aspects. The three elements and their supporting definitions are as follows:

KNOW-HOW - The sum total of technical expertness and practical skill, however acquired. KNOW-HOW has both breadth (comprehensiveness) and depth (thoroughness). Thus, a job may require some knowledge about a lot of things or much knowledge about a few things.

KNOW-HOW consists of:

Practical, specialized, technical or administrative knowledge.

Human skills in motivating, appraising, selecting, organizing or developing people, singly or collectively.

PROBLEM SOLVING - Is the amount of original, self-starting thinking required by the job for analyzing, evaluating, creating, arriving at and making conclusions. It has two dimensions:

The kind of problems to be solved.

The degree of control or guidance over problem solving.

PROBLEM SOLVING utilizes KNOW-HOW; "you think with what you know"; therefore, PROBLEM SOLVING is treated as a percentage utilization of KNOW-HOW.

ACCOUNTABILITY - Is the measured effect of the job on end results. It has three dimensions, in the following order of importance:

The Freedom to act.

The job impact on end results.

The magnitude of the end result which the job most clearly affects.

Instead of establishing point values in advance for each of the three evaluating elements, they are weighted through what is called the "profile". This simply is a percentage relationship between the values assigned to the three elements. A typical profile, for example, for a plant manager would be 33 - 24 - 43 - which means that 33% of the importance of his job is believed to be assignable to the KNOW-HOW which is required; 23% indicates the relative importance of the PROBLEM SOLVING requirement for that job; and 43% represents the importance of ACCOUNTABILITY for results of this job.

Profiles are rational and logical, and well-informed people find it possible to develop logical and consistent profiles after a very few minutes of preparation. Thus, the scales are weighted according to management judgment and not crystallized in advance by the designer of the plan.

The Guide Chart-Profile Method is a valuable tool to aid management and staff in the establishment of appropriate and acceptable salary standards.

2-10-55

Edward N. Hay

NOTES

COMMUNICATIONS AND ADMINISTRATIVE TRAINING FOR INCENTIVES

Presented to the American Institute of Industrial Engineers
National Convention at St. Louis on May 13, 1955
by
Mr. J. F. Biggane, Chief Industrial Engineer,
Maytag Company, Newton, Iowa.

Introduction

A. "Communications" - isn't that a nice general term, meaning everything and nothing?! What kind of communications are we talking about? Cleopatra communicated plenty to Marc Antony when she merely winked her eye. How quickly is the modern man put in the dog house by one look from his wife! Hasn't each one of us on one occasion, at least, done something with perfectly good intentions and has been utterly surprised at the result when our action was misinterpreted?

The communications I am talking about are the communications which take place in an Industrial incentive situation primarily between employees, industrial engineers and manufacturing supervision all the way up from the immediate Line Foreman to the Vice-President of Manufacturing. The administrative training I have in mind is that which was derived directly from a particular system of communications which I will describe later.

B. What was the Purpose of our Communications?

1. To get people to work efficiently - as evidenced by the performance percentage or earnings, in the case of an incentive system.

2. To enable people to work harmoniously. For example, there would be no "walking off" the job as our electricians did once when they misunderstood arrangements which had been made with the outside Contractor's electricians working on the same job.

3. To satisfy the need for understanding between Employees, Foremen, and Industrial Engineers. Remembering that the Foreman has years of practical experience while the Engineer has a more formal education, we cannot expect each to be able to do the other's job or even parts of the other's job! Again, we need to recognize that foremen tend to be too much employee-oriented, and engineers too management-oriented.

C. What was the Purpose of our Administrative Training?

1. To qualify Foremen and Industrial Engineers so that they could manage an incentive system for the maximum benefit of all parties concerned.

The prerequisites were a careful selection of the Foreman or Industrial Engineer before he was hired based on a preliminary interview, a testing program, and a careful diagnostic interview. This would be followed by on-the-job training, and the particular process to be covered by this talk, - an "Evaluation" to obtain "Superior Performance."

COMMUNICATIONS

I. Was there a need for Better Communications?

A. I stated that we had a need for understanding between employees and management. I do not infer that our relationship was poor. A few years ago - in the Spring of 1951 to be more exact, employee relations in the Maytag Company were going along pretty well. With reference to the incentive system particularly, reasonable success was being experienced.

1. Our old Plant had already been quite successful with incentives. Incentives had been introduced in June '46 when the Company signed its first Contract with a Union, - the CIO-UER. Before installation of incentives, production of 1200 Washers/day on the main assembly line was considered excellent. Within twelve months after installation of incentives, production with the same number of personnel averaged 1825/day. Good effort and skill were shown and the Plant as a whole averaged approximately 136% performance. Our employees were relatively long-term employees, and sit-downs occurred occasionally when Labor Standards were changed.

2. In early 1950, another Plant and a new product were created. So by 1951, when a Survey of employee opinion was being considered, this Plant was in the process of being put on incentive. The workers were youthful, 50% of them lived out-of-town, and there were frequent cases of disagreement, and sit-downs on the Main Assembly Line. Usually management had been able to work its way out of these without serious trouble.

3. About once per year we would have an Arbitration Case. In one of these concerning whether a method change had taken place, we used a movie of the operation, a college professor to testify that Work Simplification and pre-determined time systems were in good repute, and a professional consultant to present an MTM analysis of the operation. The Union contended there was no change in method even though the operator was using a different set of motions. The arbitrator dodged the issue of whether there was a method change or not, and ruled in the Union's favor by stating that, since the Tool Design Department had forgotten to date their drawing of the changed fixture, it was very possible that the Labor Standard was set after the fixture had been changed and not before.

B. Was there a need for a Survey? - Such was the state of things with our Incentive System - in the Spring of 1951! However, we were interested

in whether something more positive and constructive could be done so that both employees and management could obtain all that was possible from the Incentive System. We hoped to make a contribution in the field of Management - Employee Incentive Relationships.

First, we had to find out the facts of the situation. We had heard that the Survey Research Center at the University of Michigan, Institute for Social Research, had done work not only in the field of general social research but in Industrial relationships as well. To persuade the Center to work with us, we stressed that they had not yet examined the relationships of employees and management in an incentive situation. This could be the type of situation where because of the ticklish job of telling a man how much work he should do every day of his life, and then paying him only for how much work he actually did, some tense situations could arise. This thought appealed to them. It was decided that both Michigan and Maytag could profit from a Survey of employees ideas and opinions.

II. How did the Research Center go about taking the Survey?

Their group met with the Steering Committee of Management and with the Union separately to see what their attitudes might be toward a general Survey. The Union indicated agreement that some good might come from knowing what employees liked and disliked about their jobs, and what they expected to get out of working for the Company. The Center composed their questionnaire, tried it out on a representative group of employees, made adjustments, and the final draft was accepted by Management and Union. All of our 3200 employees were surveyed, including factory workers, office workers, line foreman, and engineers. The Survey included questions about the background of each individual, and such items as his job, wages, seniority, supervision, and his ideas about the Company and the Union.

III. What were some of the findings revealed by the Survey?

(Remembering that we were trying to find out, - how can we do a better job?) There was considerable evidence that employees were favorable to an incentive method of pay, but there were a number of problems to be overcome in developing greater satisfaction with the way the system works out. Here are some straight run findings. Refer to Slides #1 thru 6.

IV. What action was taken as a result of the Survey?

A. First we "cross indexed" replies to discover what "kind" of employees said "what". We considered what the Foremen said on these matters also. From this we tried to determine what attributes of the Incentive System needed attention. (See Slides #7 thru 16)

Based on such information, representatives of the Research Center met with the Steering Committee of Management to plan what should be done. It was decided to investigate more intensively a particular department which had incentive problems. The Porcelain Enamel Department (D-86) which had 100 employees on group and individual incentive jobs was chosen. Discussions of problems were held by the Center with personnel

of this department including employees, union stewards, foremen and industrial engineers. Herewith are some of the comments from each type of meeting:

1. Meeting with Industrial Engineers:

   a. The Center asked the question, "with all the changes it has been necessary to make in jobs in D-86 over the past six to eight months, how do you account for the way people have gone along so well with these changes? We know that people are always bothered by changes and this is understandable. But, the changes in D-86 do not seem to have met with too much resistance. How could this be explained?"

      One engineer answered: "I think a lot of it is due to the way supervision in the department has handled things. The Department Head has taken a positive approach to all matters of job changes. He has taken great pains to make sure he knows what the changes would mean and why they were being made. Also, he has done everything to see that his supervisors became familiar with these things, and has emphasized the importance of communicating all of the facts to the operators.

      I've noticed that a number of the line foremen have been making sure they know all the facts about changes and have been communicating such information to the men. Some of the line foremen are quite strict about getting people to follow job methods and trying to make a labor standard work, but they are also fair and take into account the questions and complaints the operators have about Standards that are set on their jobs.

2. Meeting with Foremen:

   a. The group stated, "Foremen should certainly explain the reasons for changes that are coming up. That is something that can mean a lot to an operator. Besides it gives the foreman a chance to talk over with the operator in advance his feelings and ideas about the change. I was an operator when the survey was taken. You have a lot of different impressions about the system when you're an operator."

   b. One foreman said, "Well, the main goal is to satisfy the production wants of the Company, isn't it? Discussion of this question revealed that striving for the production goal can run into conflict with such goals as cost reduction, quality, safety, maintaining the morale and motivation of operators, etc.

3. Meetings with Operators: - (5 different groups) resulted in the following comments:

   a. Attitudes on incentives generally (as revealed by Slides #1 & #2)

1. "The reason they like incentive pay is probably that they can make more money at incentive than they can at straight hourly".

2. "One reason why some people might not like the incentive system is that they work harder on incentive."

b. How the Incentive System works out at Maytag: (Discussion of Slides #3 thru #6).

1. "Since people were satisfied with their own standards, the fact that they are not satisfied with the way the system works out shows that they are sympathetic with other workers who may have a bad deal."

2. "Part of the dissatisfaction may be that the people don't understand the system. If they understood it, they might not be so dissatisfied."

3. "If you work out a shortcut so that you can make some money, then they come down and retime the job so that you are right back trying to make standard again. Why shouldn't the operator be able to use his initiative without worrying about losing money?"

4. "I think people would be more satisfied with the system if their ideas about doing the job were taken into account. In some departments the industrial engineers just about tell you how you've got to do it. I think the foreman and the worker know quite a lot about how jobs should be done and their ideas should count too."

4. Meeting with Union Stewards.

a. "Some of the people who were dissatisfied probably felt that their standards were too tight and that they had to work too hard to make anything on such standards."

b. "Other people would have been dissatisfied because they were on automatic machine jobs where they could do very little about getting their earnings up."

c. "Some people were dissatisfied because of industrial engineers checking their jobs if they started making pretty high earnings." A lot of people probably feel that their standards should be set properly in the first place and shouldn't be changed once they're set."

d. "If the union had more part in time studies, it would be a good check on the engineer's work and given the operators a greater feeling of protection on standards that get set on their jobs. The Union should have more say in how standards get set and whether a Standard should be changed or not."

e. "It's the idea of them just walking in, watching you and then timing, which probably bothers people. They'd like to have a chance to talk it over and get to know what it's all about."

ADMINISTRATIVE TRAINING

I. A Plant Management group was formed to review all previous findings and to make recommendations to the Steering Committee.

A. The first subject they discussed was the reaction of foremen in their meetings to the employees' statement that "foremen were not doing too good a job of explaining things about the incentive system as a whole." Some foremen had commented that they were doubtful that it is the job of the foreman to explain the working of the system to the operators. "Foremen just get a 30 hour course themselves, and as a result are not fully enough prepared in all details to explain fully."

Discussion on this subject led to the following points.

1. Should it not be the foreman's responsibility to explain the system to the operators?

2. If this is so, and some foremen don't feel it is their responsibility, does this not suggest that management all the way up the line needs to review its philosophy of operation, its lines of communicating this philosophy, and its techniques for assisting foremen in their responsibilities regarding the incentive system?

3. The foremen comments referred to above applied to the job of explaining the system as a whole. They did agree that it is their responsibility to explain reasons for standard changes and to tell people beforehand that changes are coming up.

4. It was observed that maybe higher management people expect the foreman to be expert on more things than he is capable of. Wouldn't it be wise to review just how much the foreman can be expected to know and handle expertly? Then, do not change his responsibility for administering these things with the operators, but encourage him in the practice of calling on expert assistance from staff people. In this way, decisions and policy would come to the operators through the line as it should, but would be made more accurate, complete and effective by foremen having the benefit of staff assistance.

Indeed there is evidence that D-86 is a department in which there has been an increasing tendency to function in this way, with the result that everybody feels things are better now than they were about a year ago. This last statement seems to be in agreement with Slides #17, 18, and 19 which reveal operators' feelings in a survey taken six months after the original survey. The number of operators who wish their foreman to more actively manage has increased (Slide #18); they say that foremen are taking a larger part

in both establishing Labor Standards (Slide #17), and in seeing that operators follow the described methods (Slide #19).

B. The Plant Management group also considered the comments made by Foremen and Industrial Engineers in regard to organizational goals and personal goals. Both felt that the overall goal of the organization is to maintain a healthy profit position in a competitive economy. It was also appreciated that they were responsible for furthering certain sub-goals--such as production, cost control, quality and the maintenance of a well motivated and effective working force. Particularly, foremen emphasized production, while industrial engineers emphasized cost control. Both groups also indicated that their emphasis on different sub-goals led to conflicts.

It was felt that the basis for this conflict lies to some extent in the communication channels from top plant management down through to the foreman or industrial engineer. Industrial Engineers pointed out that they felt that top management probably has the broadest view of what organizational goals should be served at a given time. They also felt that top plant management has valid and logical reasons for the things they want to place emphasis on. At the same time, it was felt that these decisions by top management and the reasons for them do not get down to the foremen and industrial engineers in the same form in which they are formulated by higher management. The result, then, is that they find themselves feeling under pressure to push one or another of the sub-goals while others are pushing for different ones.

The Plant Management group concluded that it should study ways of achieving greater coordination and integration at their own level, ways of doing a more complete job of communication and consulting with their next levels on organizational goals and ways of achieving these goals; and ways of developing in department heads the same kind of practices between them and their foremen.

. Steering Committee. -

To consider these recommendations and to take action on information resulting from the entire Survey the Center Personnel met with the Steering Committee. It was decided that if the individual foreman and individual industrial engineer could learn how to take an effective part in the foremen-employee-industrial engineer relationship, distrust would lessen and perhaps vanish. To help the foreman and industrial engineer to attain this skill it was decided to create a system of evaluation and development for each individual. The evaluation process would:

Help each individual to appraise himself.
Provide him an inventory of his skills.
Be the basis for a development program from both Evaluator and Evaluatee, and in fact for all of us and "the way we manage".

To effect this, an Evaluation Inventory Form was composed for each type of management personnel, such as Shop Supervision, Engineers, Production Control Managers, etc. The evaluation process was to start with Shop Super-

vision first since they are the group who manage the operators directly. The Form and the items to be covered were as follows: (See Slide #20):

a. General attitudes and practices relating to the Incentive System.

b. Knowledge about the Incentive System.

c. Communication practices.

d. Participation practices.

e. Management responsibilities regarding Labor Standards.

f. Concern for interests and welfare of employees.

g. Responsibilities with regard to general department and working habits of the people he supervises.

h. Influence with superiors and other management people.

i. What steps will be taken to provide his development?

A similar form has been composed for Industrial Engineers and other management personnel.

The program was to consist of three phases:

a. An appraisal of the Supervisor in relation to his Job Description, what people say he does, his results as revealed by accounting records, etc.

b. A review of the Appraisal with the man by his immediate superior.

c. A development program to meet his needs.

What was the reception of Shop Supervision to this proposal? Here are some comments from Plant Managers:

First Plant Manager: My supervision want to know how soon the Evaluation process will begin. They say it will be a big help in solving some of their problems.

Second Plant Manager: "I have never lead a conference in which there has been more interest than this. One general foreman got enough out of this first meeting to cover two meetings with his line foremen in advance of their evaluation. One foreman said he had trouble trying to explain how you feel when you disagree with a man. He thought this process would help and that he would like to take this material on down to his line foremen".

THE PROCESS OF EVALUATION

1. Comments and suggestions emanating from meetings with Shop Supervision and Industrial Engineers resulted in a guide to be used in

making the Evaluation and in discussing it later with the person involved. For each question a short discussion was given regarding both the foreman's practices and his attitudes on the subject of the question. Herewith is a typical question together with the discussion on practices and attitudes. See Slide #21.

To begin the process, the operating Department Heads were evaluated first, and by a group consisting of the Manager of Manufacturing, the Plant Manager, the Head of the Maintenance Department, the Manager of Industrial Engineering, and the Chief Technical Engineer concerned, (who would be the Tool Engineer for the Machining Department, the Process Laboratory Head in the case of the Plating Department, etc.) and Industrial Relations advisor who acts as a coach. The comment made by this group when they filled in the Evaluation form was,"We are not evaluating this man, we are evaluating ourselves!"

Discussion of the completed Evaluation was held with each Department Head by his Plant Manager. It turned out to be a much more thorough and satisfying way of two people understanding each other than had been achieved by any previous process. Incidentally, questions were asked concerning the practices and attitudes of Management on higher levels! This information was delivered to these gentlemen of the Steering Committee and caused a few changes in their philosophy.

2. The next step was for the Department Head to evaluate each of his General Foremen. The Plant Manager assisted in the evaluation to observe how much the Department Head himself was putting into actual practice from his own evaluation. The second level of management in each of the staff departments previously mentioned assisted in the task. The completed evaluation was then discussed by the Department Head with each General Foreman.

3. Finally, the General Foreman evaluated each of his Line Foreman with the assistance of his Department Head, the Industrial Relations Advisor, and the engineers in each of the Staff Departments who worked with the Line Foreman daily.

CONCLUSION

1. As a general conclusion, it may be said that many of the Manufacturing Supervisors actually made improvements in their attitudes and practices. The results still fall far short of perfection, of course, especially on the part of those who had possessed the less desirable characteristics over a long period of years. However, the enthusiasm of all foremen to make changes in themselves is encouraging.

2. We hope that this thorough individual approach will help to achieve understanding of situations and will be a source of inspiration in overcoming problems.

3. Our purpose was to strengthen people as individuals - and to get them to act, not as foremen or industrial engineers in the narrow specialized sense, but as management men in a well balanced all-around manner.

4. Our experience indicates that this system of Communications and Administrative Training is going a long way toward achieving mutual understanding and confidence, as well as high returns in the field of incentives.

Slide No. 3

"Do you think there should be changes in the Time Study and Incentive System at Maytag?"

	P-1	P-2	Ind Inc	Grp Inc	Non Inc	TOT	FMN TOT
The Time Study & Incentive System is all right as it is now	23%	19%	17%	19%	26%	22%	47%
The Time Study and Incentive System should be cut out and everybody should be paid by straight hourly rates	16	14	13	14	17	15	5
The Time Study & Incentive System should be kept but it should be handled differently than it has been up to now	48	58	66	62	37	51	41
N.A.	13	9	4	5	20	12	7
Total	100%	100%	100%	100%	100%	100%	100%
Number of cases	1577	922	722	681	1096	2499	196

Slide No. 4

"How do you feel about the labor standards on most jobs?"

	P-1	P-2	Ind Inc	Grp Inc	Non Inc	TOT	FMN TOT
Most of them are too tight	57%	73%	74%	74%	48%	63%	12%
Most of them are about right	33	20	23	22	35	28	73
Most of them should be tighter	2	1	1	2	3	2	6
N.A.	8	6	2	2	14	7	9
Total	100%	100%	100%	100%	100%	100%	100%
Number of cases	1577	922	722	681	1096	2499	196

Slide No. 5

"How do you feel about the labor standard on the job you are on at the present time?"

	Inc P-1	Inc P-2	Ind Inc	Grp Inc	INC TOT
Very satisfied	15%	9%	15%	10%	13%
Fairly satisfied	40	35	39	40	39
Neither satisfied nor dissatisfied	15	15	15	14	15
Fairly dissatisfied	13	14	13	13	13
Very dissatisfied	11	23	13	17	15
N.A.	6	4	5	6	5
Total	100%	100%	100%	100%	100%
Number of cases	942	461	722	681	1403

Slide No. 6

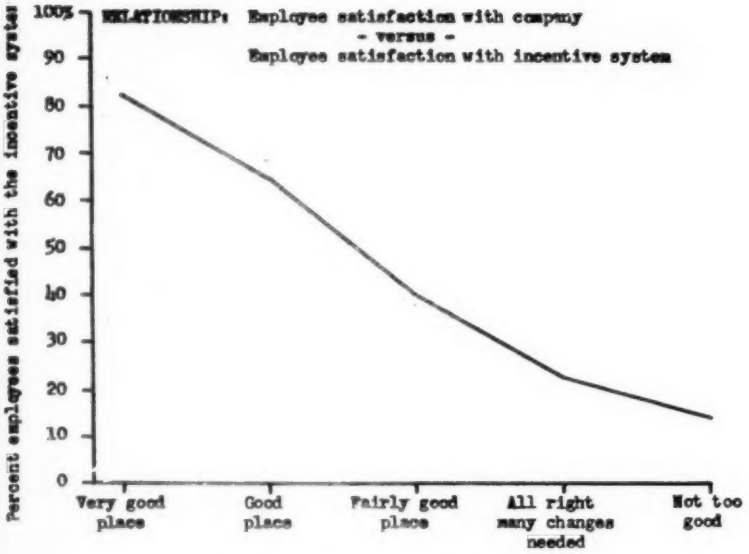
"How do you think the following people feel about most labor standards?"

	Time Study Men	Top Management People	Top Union Officers	Line Foremen
They feel most standards are too tight	2%	3%	36%	11%
They feel most standards are about right	32	23	16	40
They feel most standards should be tighter	22	25	3	6
I don't know how they feel about standards	37	42	38	33
N.A.	7	7	7	7
Total	100%	100%	100%	100%
Number of cases	1403	1403	1403	1403

SLIDE NO. 7

Fig 1

Figure 1

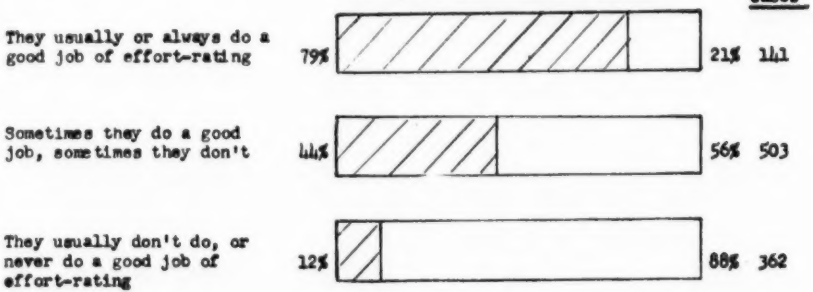


SLIDE NO. 8

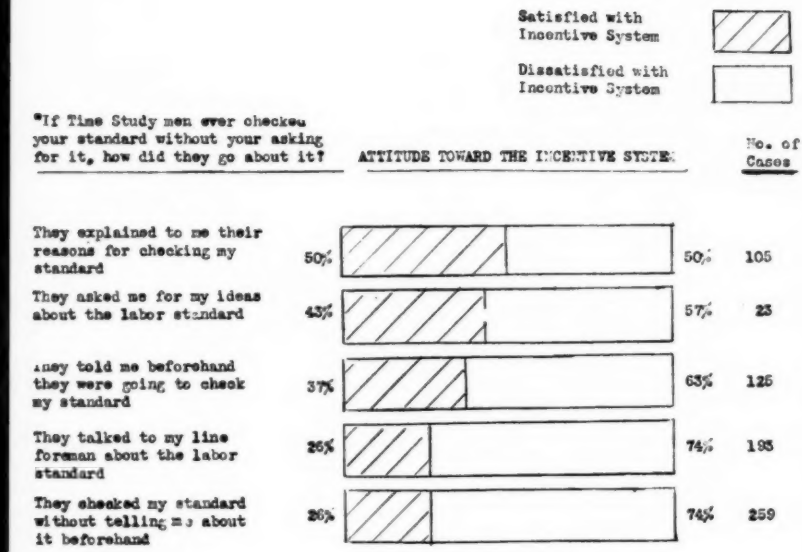
"How good a job do you feel the time study men do when they "effort rate" a man on a job?"

Satisfied with Incentive System

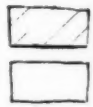
Dissatisfied with Incentive System



SLIDE NO. 9


Satisfied with Incentive System
Dissatisfied with Incentive System
"If Time Study men ever checked your standard without your asking for it, how did they go about it?
ATTITUDE TOWARD THE INCENTIVE SYSTEM
No. of Cases
They explained to me their reasons for checking my standard
50%
50%
105
They asked me for my ideas about the labor standard
43%
57%
23
They told me beforehand they were going to check my standard
37%
63%
126
They talked to my line foreman about the labor standard
26%
74%
193
They checked my standard without telling me about it beforehand
26%
74%
259

SLIDE NO. 10

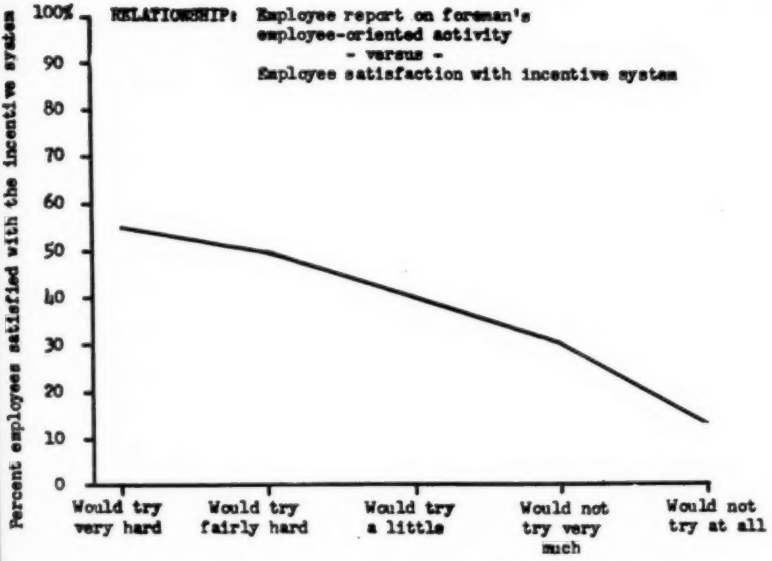


"In timing jobs, what do the time study men try to do?"	ATTITUDE TOWARD INCENTIVE SYSTEM		No. of Cases
Satisfy top management	38%	62%	1448
Set a fair standard for the job	84%	16%	377
Satisfy the men	82%	18%	83

SLIDE NO. 11

Fig 5

Figure 5

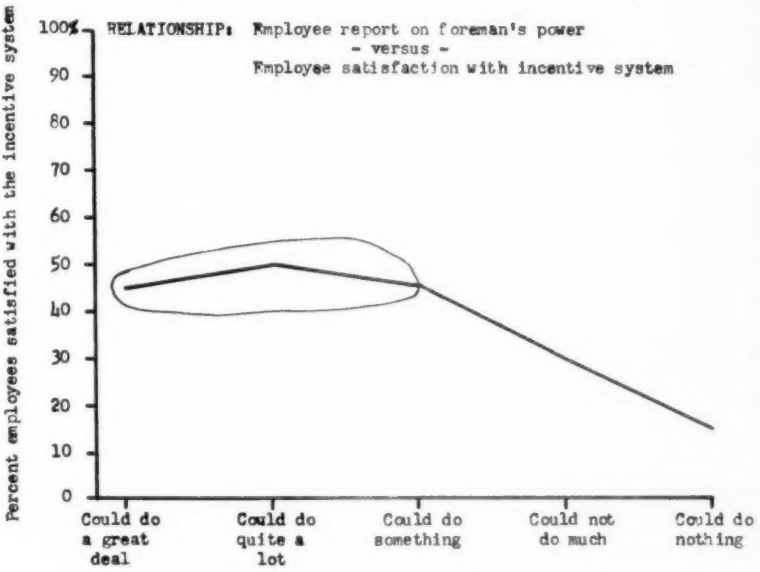


"If your line foreman thought that the labor standard on a job was too tight, would he try to do something about it?"

SLIDE NO. 12

Fig 6

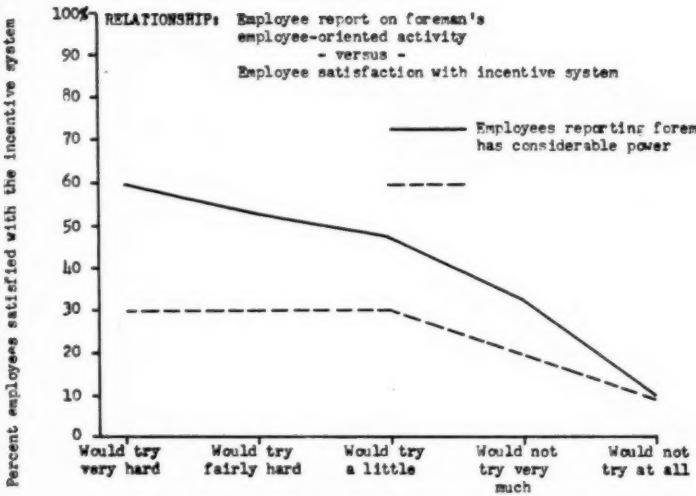
Figure 6



SLIDE NO. 13

Fig 7- B

Figure 7



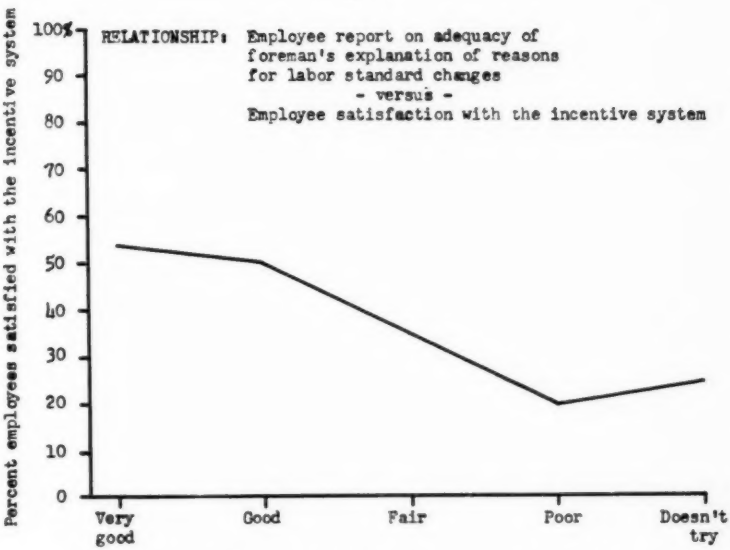
"If your line foreman thought that the labor standard on a job was too tight, would he try to do something about it?"

1. The term "power" is used merely to designate whether the foreman is seen by employees as being able to do something to effect changes in labor standards.

SLIDE NO. 14

Fig 2

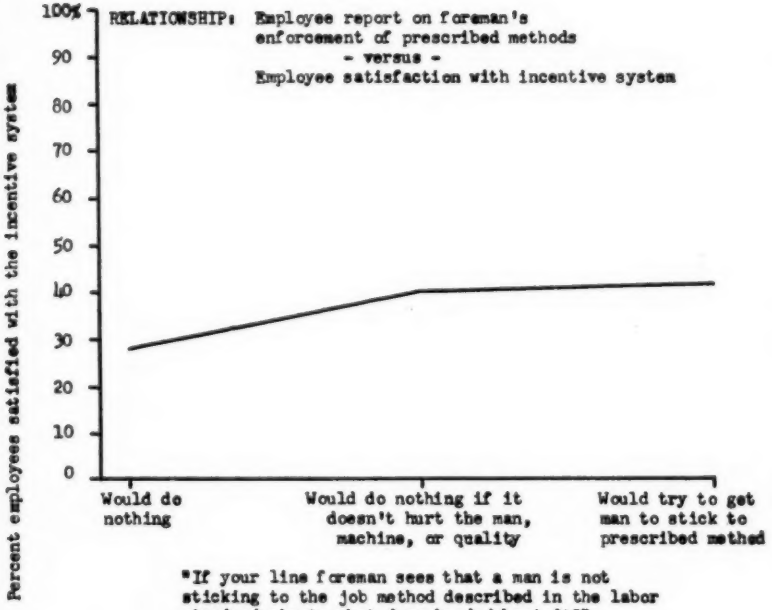
Figure 2



SLIDE NO. 15

Fig 3

Figure 3

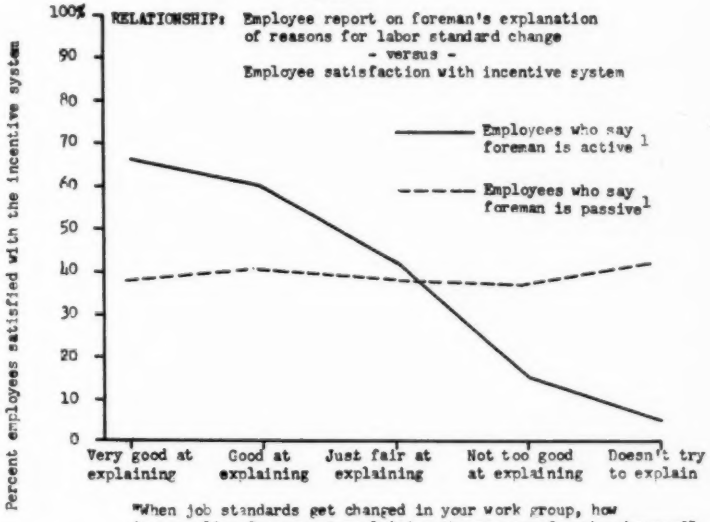


"If your line foreman sees that a man is not sticking to the job method described in the labor standard sheet, what does he do about it?"

SLIDE NO. 16

Fig 4-B

Figure 4



"When job standards get changed in your work group, how is your line foreman at explaining the reasons for the changes?"

1. The terms "active" and "passive" are used merely to designate whether foremen are seen by employees as trying (active) or not trying (passive) to get people to follow the job method described in the labor standard sheet.

SLIDE #17

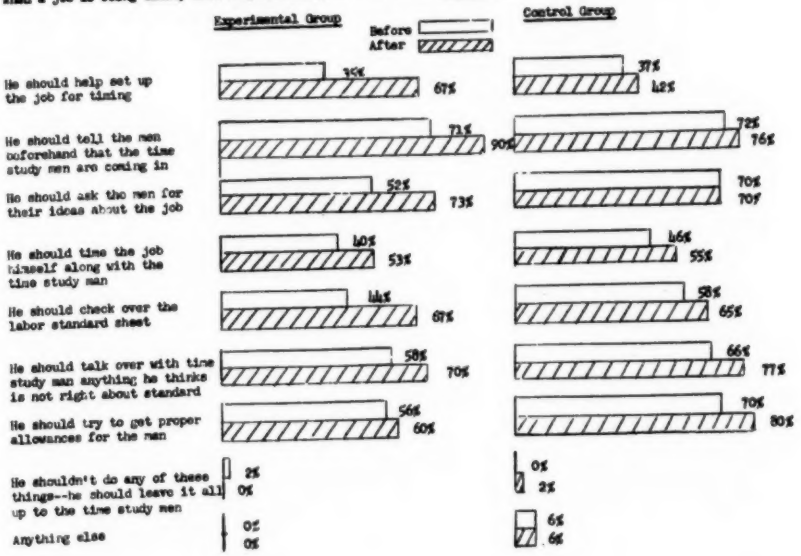
THE MATTAO STUDY

December 7, 1953

Before-After Results on Feedback Experiment in D-86

For Incentive Workers Only

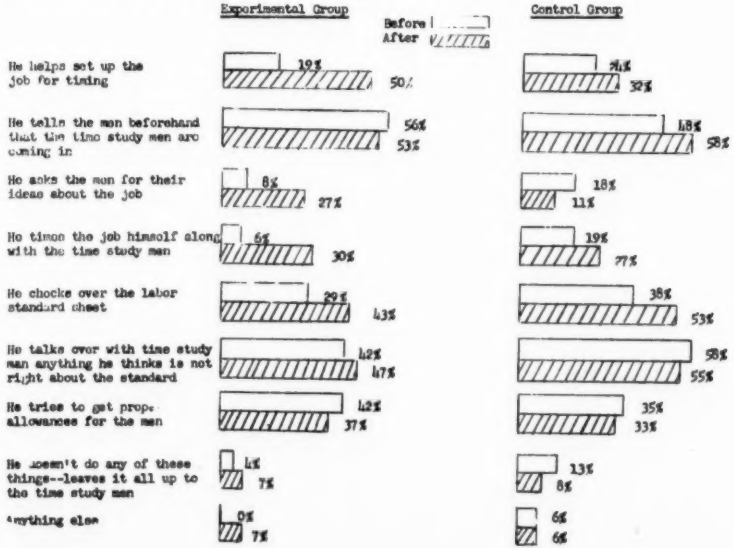
When a job is being timed, what do you think your line foreman should do?



Before-After Results on Feedback Experiment in D-86

For Incentive Workers Only

When a job is being timed, what does your line foreman do?

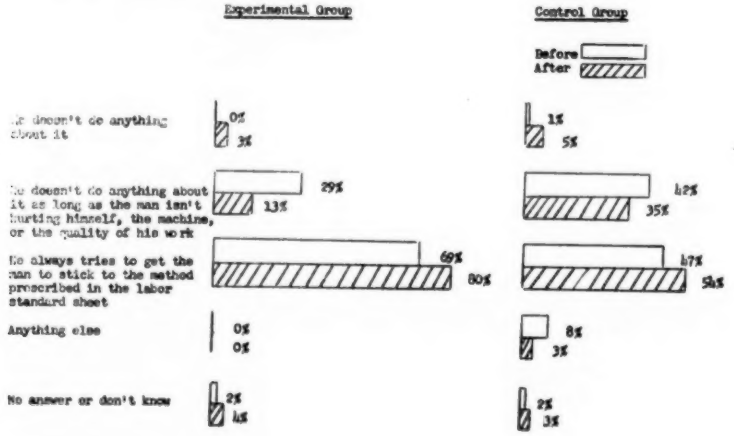


THE MAYTAG STUDY SLIDE #19 November 24, 1953

Before-After Results on Feedback Experiment in D-86

For Incentive Workers Only

If your line foreman sees that a man is not sticking to the job method described in the labor standard sheet, what does he do about it?



Slide No. 20

(Rev. 5-12-54)

Line Foreman Development Inventory

Name _____ Date _____

By _____ Department _____

In carrying out their jobs, management people are required to use a variety of skills. People differ in the skills at which they are most proficient. A supervisor may be strong on some skills, fair on others, and weak on still others. Thus, all management people probably need some development in one or more skills. Listed below are a number of specific aspects of a supervisor's job. As a department head you probably have an idea as to what constitutes superior performance on each of these aspects. Please check on the scale for each job aspect, how much development you feel this supervisor needs in order to reach this superior performance level. The comment spaces after each job aspect will allow you space for a specific comment which you feel you need to further explain your rating.

A. General attitudes and practices in relation to the incentive system.

1. Working constructively with all staff departments (tooling, methods, safety, processing, industrial engineering, etc.) to determine proper working methods.

Needs a lot of development	Needs some development	Needs very little, if any development

COMMENTS: _____

2. Working constructively with industrial engineers to establish proper labor standards.

Needs a lot of development	Needs some development	Needs very little, if any development

COMMENTS: _____

3. Having the attitude that increased incentive earnings should follow only from attaining higher skill and exerting more effort than is required to earn "normal maximum" as specified by the labor standard.

Needs a lot of development	Needs some development	Needs very little, if any development

COMMENTS: _____

SLIDE #21 (Rev. 5-10-54)

EXPLANATIONS FOR EACH ITEM ON THE LINE FOREMAN DEVELOPMENT INVENTORY

From a series of conferences with the Michigan Study Steering Committee, Department Heads and General Foremen the following explanations were developed in order to further define the various meanings and concepts which these groups felt should be included in each item on the inventory. The general subjects and items from the Line Foreman Development Inventory are repeated and underlined with the explanations following each item.

A. GENERAL ATTITUDE AND PRACTICES IN RELATION TO THE INCENTIVE SYSTEM.

(NOTE: The explanations for each item under Section A have been divided into two areas which are "Practices" and "Attitudes".)

1. Working constructively with all staff departments (tooling, methods, safety, processing, industrial engineering, etc.) to determine proper working methods.

Practices

1. The foreman should:
   a) Check tooling with tool engineers and equipment with maintenance engineers
   b) Review methods with Methods and Incentive Engineers
   c) Work closely with Inspection, including Quality Control and Final Inspection to insure quality standards
   d) Check Safety precautions with Safety Engineers and others
   e) Check materials and schedules with Production Control
   f) Select a normally-qualified operator to run the job
   g) Make a pilot run

2. He should review the method with his own department supervisor, as well as with the staff people noted above and make sure they incorporate his ideas into the method.

3. Talks it out with industrial engineer and tries to make sure the industrial engineer's ideas get incorporated. Trains the engineer in his own shop know-how.

4. After decision is made to use a given method, he gets behind it and does his best to see that it gets a good try.

5. If convinced, later, that a change in method would improve the job, he puts in a request for operational change.

Attitudes

1. Has the attitude that it is his responsibility to make sure the best possible method gets set on the job.

2. Is convinced it is important for him to work harmoniously with staff people rather than to criticize them.

3. Is pleasant, receptive and stimulating to his own employees, encouraging them to put forward their ideas on methods.

NOTES

WORK SAMPLING -- A COST CUTTING TECHNIQUE

C. L. Brisley
Industrial Engineering Manager
Wolverine Tube

One of our prominent A.I.I.E. members, an Industrial Engineer in a small company in our city of Detroit, became so frustrated over the resistance to change that he had encountered with many of his management people, that he went off base mentally and had to be sent to an insane asylum just outside the city. A few weeks after he had become an inmate of this institution, with some apprehension, I decided to visit him. To make me more disturbed, when I arrived at this institution, I was ushered into a very large room where he was with a great many other inmates. This was quite an uncomfortable feeling. However, he appeared very normal to me. Nervously, I chatted with him. Suddenly, the whole room vibrated with a burst of laughter. This annoyed me considerably. Then someone shouted, "17", and there was another burst of laughter. I said to my A.I.I.E. brother, "What's this all about?"

"Oh," he said, "this is a work Simplification project."

At this point, remembering that he was having a bit of difficulty upstairs, I asked, "What do you mean?"

He then reviewed briefly his experience at this institution. He said, "When I first came here, the boys were telling the same stories over and over. So, I wrote them down in this notebook and numbered them. Now they don't bother to tell the stories, they just shout the number and everyone remembers the joke and laughs." He said, "Maybe I couldn't get work simplification projects into effect in the plant, but the boys here are sold on it."

He was so enthused about this project that I forgot about where I was and asked to review the notebook. I found in it some excellent jokes and thought to myself, "This is a splendid idea." So, I picked out one which I thought would go over and stood up in a conspicuous place and shouted, "Number 21". Instead of laughter, there was dreadful silence. I quickly called out another number, "Number 43", and again, I got the same treatment. In desperation, I looked at my inmate friend and said, "What is the matter?"

He looked at me and said, "Chet, are you crazy? Don't you know that some folks can tell a joke and some just can't?"

This is why I did not begin this talk with a story. Also, much of what I have to present to you is not new to you, for I stole it from someone else. I could save you much time by

simply calling off numbers if the numbers had any significance to you.

Work Sampling Based on Laws of Probability:

The purpose of this presentation is to give you a little of our experience in this technique called "Work Sampling". Since you were a small child you have been very familiar with sampling, for children love to lick the remaining frosting from the bowl while their mother is baking a cake. They never question but what all the frosting tastes similar to the sample which they have taken.

The first question that I am sure you would like to have me answer is, "What is work sampling?" This technique is based on the laws of probability. Most people when they attempt to explain the laws of probability resort to some gambling game. One of the simplest gambling games in the world is the tossing of a coin. For all of us can see that in the tossing of a coin we have two possibilities. We will either have Heads up or Tails up. The laws of chance say that in one hundred tosses of a coin we should have 50 Heads and 50 Tails. This is a simple ratio which involves the average possibility. It does not mean that it will always happen; for in 100 tosses you may have Heads come up 60 times and Tails, 40 times. It has been proven, however, that as you increase your number of tosses, this law of averages becomes increasingly more accurate. Or, saying it another way, the percentage of possible error decreases.

In an example such as this, it is easy to ascertain the mathematical probability of obtaining either Heads or Tails, but as you so well know, many other problems are not so easily determined. For example, John Smith died yesterday at the age of 40. From large numbers of facts gathered by the insurance actuaries, mortality tables have been constructed to serve as a basis for computing the amount of your and my life insurance premiums. From these tables they have determined that of 100 babies born today, 70 will be alive forty years from today. However, if we compare English, French and American mortality, we shall find no two of them alike. This is because life is enormously complex and life expectancy varies with the type of work one does, the climate, heredity and many other variables.

Insurance companies have used these mortality tables for years to guide them. But the subject of the use of probabilities has become widely known to business only since the war. The armed services has helped greatly in promoting the use of these techniques, and thus it has become possible to formulate intelligent policies in the business world and to construct experiments and make predictions.

Most of us are sort of gamblers at heart. Few of us can resist an occasional attempt to beat the odds at a game of cards,

or the one-armed bandit slot machines. So often management operates its plants like slot machines. Whenever they have problems they play hunches in solving the problems. This may seem odd to you, but it would be better to follow the example of the professional gambler, who for years has been trimming his opponent with systematic regularity. His system and his success can't all be luck; nor is it intuition. It is no less than his ability to foresee the winning chances of certain combinations and plays. He is basing his betting on an intelligent application to the laws of chance. These same laws can be used in a somewhat different manner to take the gamble out of engineering, the teaching profession, hospital administration, management and many other administrative problems.

The same general laws of variation that govern gamblers' luck may be discovered in the batting averages of baseball players, intelligent quotients of people, the heights of soldiers, or in the various elements of an executive's, scientist's, or engineer's job. This gamble can be analyzed, facts can be ascertained, and you can determine how effectively people are utilizing their time.

(TELL TENNIS STORY)

The Work Sampling Study is a sampling method of evaluating possibilities that an operation will be performed in a prescribed manner. Just as in the case of tossing a coin, we can very easily pre-determine what the laws of chance are. In the case of executive behavior or clerical operations, we have to toss the coin a good many times to obtain a high degree of accuracy in the sample. Or, to find out what the possibilities are. We must have some method of obtaining a sample to determine what a group of people or machines may be doing.

According to definition: "A sample comprises a selection of a number of objects from the total number of objects. If these samples are chosen in such a manner that one object has as good a chance of being selected as another, we have what we call a random sample.

Theory of Work Sampling:

A simple illustration will present the theory of Work Sampling. Supposing we break down a job into four parts: (SHOW SLIDE) Set-up, Operating Cycle, Maintenance, and Personal Time. In order to illustrate, let us assume that we select just one machine and we make ten observations at random intervals during the day.

At the end of our day, our tally will be as follows:

Element	Observations	Ratio	Percent
Set-up	//	2/10	20%
Operation	~~HHL~~ /	6/10	60%
Maintenance	/	1/10	10%
Personal	/	1/10	10%

This gives us a ratio as compared to the total of 6 to 10; 2 to 10; 1 to 10; and 1 to 10. Or, converting that to percentages 6/10 is 60%; 20%; 10%; and 10%. This is an example of studying a machine operation. Let us analyze an engineering job. (SHOW SLIDE)

Here we break the job down into four elements: Receiving Instructions, Drafting, Filling our Engineering Orders, and Personal, and here we have tallies at the end of the day as we did in the first case.

Element	Observations	Ratio	Percent
Receiving Instructions	//	2/10	20%
Drafting	~~HHL~~ /	6/10	60%
Filling out Eng. Order	/	1/10	10%
Personal	/	1/10	10%

The ratio runs 2/10, 6/10, 1/10, and 1/10. And the percentages run 20%, 60%, 10% and 10%. The theory is that if we multiply 20% times the 480 minutes that these people may work during the day, we would arrive at 96 minutes for Receiving Instructions in the case of the Engineering study, or 96 minutes for Set-up in the case of the Machine study. Obviously, we have made only ten observations and the percentage of error would be quite great. But, if we increase these ten observations to 100, 1,000, 5,000, or 10,000, you can see that the percentage of error would decrease.

History of Work Sampling:

First, I shall give you a little historical background on the technique of work sampling. It was first introduced in this country by Professor Robert Lee Morrow, who was then with New York University. He presented a paper on the subject before the 1940 Annual Meeting of the American Society of Mechanical Engineers. The April, 1941, issue of "Mechanical Engineering" contained the following excerpt with respect to

this paper.

> "In searching for a better way to determine delay and variation allowances, a method used by L.H.C. Tippett, in the English Textile Industry, described in the JOURNAL OF THE TEXTILE INSTITUTE TRANSACTIONS, February 1935, was put to practical tests in three separate industries, by graduate time-study students, under the direction of the Department of Administrative Engineering at New York University.
>
> "These studies, the results of which were reported in Mr. Morrow's paper, show the new method to be a statistical technique, highly practical, and productive of more accurate results at less cost than methods previously employed. As every operation, in every industry on which cost or wage payment standards are set, must include the allowances mentioned, the importance of this new method is evident. The new method is called 'ratio delay study'."

As you will note, the technique was first introduced in this country in 1940, 15 years ago, and was called the Ratio Delay Study. It was introduced in England by Tippett in 1935, 20 years ago, and was called the Snap Reading Technique.

As a result of Professor Morrow's work and the experience of L.H.C. Tippett in the English Textile Industry, a great many companies have made use of this approach. Perhaps your company is using the approach. Wolverine Tube has made use of it to a great extent for the past ten years.

Many who have used the Ratio Delay technique have envisioned many more uses for this concept. A random observation method applies to any activity on which all the facts are needed to understand what is happening, and to find out where the opportunities for cost reduction lie. Ratio Delay actually describes only a part of the broad use of the tool. As an indication of the expanded concept of the application, Mr. Edwin H. Schaffer, Industrial Engineer of the J. E. Ogden Company in New Jersey, changed the name to "Observation Ratios", in an article he wrote in FACTORY Magazine in July 1941.

In 1952, I wrote an article for FACTORY on this technique. Mr. Harry Lee Waddell, then Editor of FACTORY Magazine, introduced the term "Work Sampling" for this new concept. This term, from a psychological point of view, places the emphasis on the word "work" rather than on the word "delay", as in the case of ratio delay. We, therefore, prefer the term "Work Sampling", and it is catching on rather widely and is being used throughout the United States and Europe.

Whether we call the subject, "Work Sampling", "Ratio Delay", "Snap Readings", "Observation Ratios", or by some other term, they still mean the same thing.

Applications of Work Sampling

Time Study Allowances:

Since 1944, Wolverine Tube has been making use of this approach to establish time study allowances. As you Industrial Engineers know, allowances are added to the time study to take care of such requirements as personal time, time to go to the crib after tools, waiting on stock, etc. These allowances are added to the time study to take care of the various things that happen on the job beyond what might be observed during the actual time study period.

For many years, this type information was obtained by taking all day time studies and then setting up percentages for allowances. By making use of the work sampling study technique, these allowances can be determined with great accuracy and with much less work on the part of the Industrial Engineering Department.

Work Sampling at the Decatur, Alabama Plant:

When our new Decatur, Alabama Plant began operating in 1948, it was equipped with the most modern machines. We had many production problems in the beginning. Inexperience with the new equipment caused some "bugs" and needed improvements in the equipment caused others. In fact, we had so many problems, we hardly knew where to start. We needed something to tell us quickly of the location and the relative magnitude and causes of our more serious problems.

Our experience with the use of the work sampling technique in the Detroit Plant for time study allowances suggested the use of the technique on our new plant problems.

Harper Hospital:

This technique was applied at Harper Hospital in Detroit. About three years ago, the management of Harper Hospital came to Wayne University and to the Detroit Chapter of the Society for the Advancement of Management for help with respect to their problems. As a result, a joint committee was set up comprising members of the S.A.M. and Professors of Wayne University to help the hospital in the solution of these problems. It was apparent that the higher echelons of the nursing personnel were doing some jobs that lower skilled personnel could be doing.

The administration of the hospital were anxious to get to the bottom of this problem because of the shortage of nurses. We suggested that they make use of the Work Sampling technique. As a consequence, I spent some time with three hospital administrative understudies and showed them how to make a work sampling study.

The first study showed that Head Nurses were spending about 20% of their time charting, a job for non-supervisors. The study also showed that registered nurses spent much time running errands for patients and performing menial tasks. Reassignment of duties gave the professional work to the nurses and other work to nurses' aides, orderlies and messengers. The result has been that the same force of nurses now care for more than twice as many patients in a test unit now set up at the hospital. This program has had far reaching influence.

Shortage of Engineers Problem:

The problem with respect to the shortage of engineers is quite parallel to this shortage of nurses problem. From April 17th to May 2nd, 1952 at our Decatur Plant, the Work Sampling technique was used in analyzing engineering work. The Plant Engineer is very alert to efficient methods and the study reflected his effectiveness. The approach was as follows:

We first consulted with the Plant Manager, who gave us permission to take up the proposition of a Work Sampling study with the Factory Manager. When the Factory Manager was approached, he called in the Plant Engineer. In this meeting, the Supervisor of Industrial Engineering at the Decatur Plant and the Manager of Industrial Engineering presented the general approach and reminded the Factory Manager and the Plant Engineer of the success we had had with the work sampling technique on production. The Harper Hospital approach was also emphasized. We pointed out that it was our opinion that the shortage of engineers and the shortage of nurses problem were parallel. We, therefore, suggested that a work sampling study be made in the Engineering Section. The Plant Engineer readily agreed and set a time for us to meet with him and his engineers.

At the meeting, the engineers were fully cooperative. It was pointed out to them that the whole program was designed to enhance their jobs and to take away from them clerical work and menial tasks if possible. It was also pointed out that they would participate in the decisions that were made.

It was decided to make a 14-day study. This required two observers. One observer remained in the Engineering Office to indicate at random intervals what each man was doing. If he was on a plant trip, he was marked as being in the plant. Another observer with a stop watch made random trips with the engineering draftsmen to determine the walking time and the

time to perform various duties in the plant.

The observers and the engineers began work at 8:00 A.M. The observer assigned to the engineers making trips to the plant simply accompanied the first engineer that went to the plant. So that the observer was not conspicuously time studying the engineer, no conventional time study board was used. The observer started his watch, slipped it in his pocket and then timed the engineer when he arrived at his project. The observer accompanied the engineer, regardless of the length of the assignment, for it might take 15 minutes or 3 hours.

After the 14-day period, 252 trips had been made. The average trip was approximately 27 minutes. Each engineer spent 26 minutes per day walking. Since there are 5 engineers, this amounts to 2 hours and 10 minutes per day. As a result of this study, the following decisions were made for the purpose of utilizing the engineers' time more effectively:

1. Consolidate trips to the Plant.
2. Make use of motor skooters or bicycles to reduce walking time.
3. Stores Section should train someone to check obsolete items.
4. Telephone could be used more.
5. Explore possibilities of using dictating machines instead of taking notes.

Work Sampling our Top Executives:

Two years ago I had the brainstorm of making use of the Work Sampling technique on our executives. I found that making a behavior study of top executives was very interesting. If you ask an executive, "What do you do?", if he is a Controller he will say, "Oh, I'm responsible for budgets, accounts receivable, accounts payable, credit, and the general financial problems of the business." Then you say, "Do you do all of that?" Then in a somewhat floundered manner, he will say, "No, but the people under me do." Then you press the question and say, "But, what do you do?" At this point he does not know what to say, for he does not know exactly what he does.

In the past two years, we have made two executive work sampling studies (SHOW SLIDE). We found that our executives spend most of their time talking. We have used this term in the broad sense, meaning COMMUNICATIONS. The term "talking" proved out to be a good word to break down the study for this presentation.

The two groups involved were the top two levels of management at Wolverine Tube where we have a committee advisory type organization. The Division Advisory Committee is a group of executives reporting directly to the General Manager. They are, the two Plant Managers (one in Decatur and the other in Detroit), and staff people, such as the Director of Industrial and Public Relations, Director of Purchases, Director of Sales, Controller, Assistant Controller, Assistant to the Vice President and General Manager, the Washington Representative, and the Director of Operations.

The Director of Operations is over the #2 level group called the Control Committee. In this group is the staff of engineers and production control people. They are the Production Development Engineering Manager, Technical Engineering Manager, Plant Engineering Manager, Production Planning Manager, Traffic Manager, Quality Manager, Production Manager and Industrial Engineering Manager, that being myself.

The purpose of the study was to analyze the percentage of time being expended by our top executive group on various categories of work. The activities of these people were broken down as follows:

Distribution of Management's Time

Element of Work	Division Advisory Committee	Control Committee	Average
T-Talking on telephone, to visitors, people reporting directly and indirectly	38%	28%	33%
A-Attending meetings, (regularly scheduled and special meetings)	9%	11%	10%
L-Letter writing and report writing	8%	6%	7%
K-Keeping abreast by reading letters and published material	13%	10%	11.5%
I-Incidental clerical work	1%	1%	1%
N-New developments through creative thinking	2%	1%	1.5%
G-Gone from office	29%	43%	36%

This study was made by an observer passing each manager's door at random intervals and recording by tally mark as shown earlier by the illustrations of the study of engineers. (SHOW SLIDE AGAIN) About twenty trips per day were made.

After the study was completed, we made up a form showing the percentage of time that each executive spent on each activity, and a comparison with the average, the low of the group and the high of the group. I then reviewed and interpreted this data to each person so that he could analyze his own operations for improvement.

This study did much to stimulate people in management to utilize their time more effectively.

Two examples will show you the type of improvement made. Nearly all the members of this grouppurchased dictating equipment. This means that the manager can read his mail once and answer it immediately. He can also give his secretary instructions to carry out at her convenience.

It was found that very often when one or two get together in an office, the telephone rang and the person in whose office the discussion was taking place would talk on the telephone for twenty minutes while the others would "twiddle their thumbs". In analyzing the total amount of time that this occurred, it was decided by some of the managers to have the secretary act as a buffer---- and to have the person call back later, or make arrangements to call the person just as is done when a meeting is being held. Some exceptions are allowed, of course. If a superior calls, a secretary would make sure that these calls went through to her superior.

"There Goes the Bell":

Professor Leo Moore, from Massachusetts Institute of Technology, and who is a friend of mine, sent me a cartoon from the Boston Herald, entitled "There Goes the Bell". In the corner was a caption, "In a Boston Company the bell rings 30 times a day and when the bell rings each person records what he is doing".

The first picture showed a blonde and a brunette waiting on an employee in the cafeteria. The bell rings and they both drop a cup of coffee which they are holding, in order that they might make an instantaneous recording.....etc. I showed this cartoon to the Industrial Engineering Supervisor of our Decatur Plant, and he immediately grasped the idea and decided to make a study of the industrial engineers. He used random numbers, converting these to various times during the day and gave a list of these times to his secretary. He used a photographic dark room clock, which his secretary would re-set each time it rang. Every time the clock rang, the members of the department

would make a tally mark on a form which they had predetermined. Our people in Industrial Engineering have the occasion to go out into the plant on assignments quite often. Each Industrial Engineer was given a stop watch. As he was about to leave, he would start his watch and place it on top of his desk. When he returned, his watch on top of his desk would remind him to record where he had been and what he was doing. At the end of the day, he should have a total of 40 tallies; if he had 32 recorded, he recorded the other 8 under "special assignments" in the plant. When a sufficient number of studies were taken, each member in the department analyzed his own activities and made out suggested written improvements for the utilization of his time. These were reviewed by each man with his supervisor and the supervisor either agreed or disagreed with the Industrial Engineer with regard to his recommendations. Many improvements came about by this process.

Clerical Studies:

We used the same approach with our clerical workers in the Division Office. In this case, instead of using a photographic dark room clock, we used door chimes on each end of the office. We punched holes in a time clock tape on a random basis, and each time the bell rang in the office, the clerical people recorded their activities. Each day we changed the tape on the clock. At the end of the study, the supervisors reviewed the activities of their group in about the same manner as did the Supervisor of Industrial Engineering.

Conclusion:

David Sarnoff, Chairman of the Board, Radio Corporation of America, made this comment recently in the January issue of FORTUNE Magazine:

> "The last 100 years have been no more than a split second in human history; yet, they have compassed more technological achievement than all the millenia that preceded. The harnessing of electricity, the demonstration of the germ theory of disease, the development of anesthetics, the evolution of mass production, the development of electronics, the splitting of the atom ----- these are only highlights.
>
> "Mark the increasing speed at which these things have come. It is not a case of continued increase, but of continued acceleration of increase."

Evangeline Booth, the great leader of the Salvation Army made this statement:

> "Time is not ours; it is but loaned to us. All we have to do with it is to use it well and be grateful for it."

We of the Industrial Engineering profession have a great challenge, for we are charged with the responsibility of helping management and production to utilize their time more effectively and thereby accelerate the increase in new and better things to come, for of all the natural gifts of life, time is the most precious.

NOTES

A TRADE UNION VIEWPOINT OF STATISTICAL PROCEDURES IN INDUSTRIAL ENGINEERING

by
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Textile Workers Union of America, CIO

Address before the 6th Annual Conference of
American Institute of Industrial Engineers
St. Louis, Missouri - May 12, 1955

Engineers in the civil, mechanical and related fields are constantly dealing with quantitative data and expressing their findings with mathematical symbols and formulae. The early industrial analysts, having been recruited primarily from the mechanical engineering ranks, adopted the title "engineer" and patterned their methods of presentation after those employed in the classical engineering professions. So intent were they in modeling themselves after these prototypes and emphasizing the mathematical character of their art, that many came to believe a facility in manipulating arithmetic data and the expression of judgments in quantitative terms elevated their practice to the plane of scientific inference. This propensity toward arithmetical expression was reinforced by an inarticulated sense of insecurity hovering behind the bold front practitioners presented to their clients and the outside world. They sought to endow their work with a scientific veneer and thereby place their procedures beyond the ken of laymen. Elementary but sometimes seemingly complex mathematical formulae were employed to achieve the desired end. This facade of omniscience has been slowly eroded by years of criticism, and the more sincere time study advocates now acknowledge that their findings are basically value judgments, the validity and reliability of which cannot be objectively established.

Statistical terminology held a particular fascination for the industrial engineer because it added an impression of precision to his findings. Unfortunately, however, many engineers who lavishly employed statistical terminology and symbolism have been inadequately schooled in the theory and methodology of statistical inference. Moreover, the profession, until recently, has turned a deaf ear to those statisticians who, upon examining prevailing time study applications, concluded

* Paper prepared in collaboration with Sumner Shapiro of the Research Department of the Textile Workers Union of America.

that the practice proceeded on shaky mathematical grounds. (1) Many time study advocates have harbored an uncontrollable penchant for rejecting statistical methodology whenever the findings it produced ran counter to the desired conclusions. The statistician's care in assembling his data and his persistence in limiting himself to rigorously proven procedures for the analysis thereof are foreign to the industrial engineer's philosophy. The latter's devotion is restricted to the derivation of the employees' work potential on the job, and he insists upon injecting value judgments he requires to make such an evaluation.

Early "Statistical" Formulae for Analyzing Observations Abandoned

Frederick W. Taylor and his earliest associates concentrated on the analysis of the work place and the workers performing within it. Their original interest centered on developing higher individual output. In devising their procedures, they hypothesized a number of principles which they soon came to accept as scientific fact. One was that the time study technique was truly scientific rather than what it was in fact - a rationalized procedure for formulating judgments. At its inception this art was the primary tool of the industrial engineer and until this day, trade unionists as well as many practitioners themselves presume that the ability to make time studies is the sole skill of industrial engineering. Attention has been focused in this paper on this aspect of industrial engineering because it is the phase of the engineer's work of greatest immediate interest to the worker.

The early practitioners were intent upon developing a "science" of time study. They recognized the desirability of minimizing the significance of personal judgment. Following in the path of the engineering professions, they sought to provide the industrial engineer with handbooks of formulae and data from which to construct specific time values and work standards. In such a manner the individual observer followed a prescribed methodology and presented consistent results. He could shed all responsibility for the correctness of the reference tables or procedures, for these were supposed to be accepted as scientific facts. This convenient procedure for placing the time study results beyond the pale of challenge of the worker at the bench who, though less articulate, generally possesses greater knowledge of the job itself, is still the dominant aspiration of some practitioners, as is illustrated by the "predetermined time-motion" devices currently being marketed.

Early practitioners, therefore, developed a number of fixed

but alternative "best methods" for "statistically" formulating their judgments. These techniques related to the determination of representative element times, an end not to be achieved by traditional statistical approaches. They sought a method of justifying the selection of a specific element time value from a group of widely distributed time values. Merrick "patented" the minimum time approach. The time study man selected the minimum observed time and added to it a number of allowances specified by the Merrick charts. To add an aura of science, the time study man was instructed that the minimum time should represent at least ten percent of the total observations. This approach permitted the time study man to transfer the responsibility for making judgments to the compiler of the charts, without actually defining the degree to which these tables fitted the specific use. It misrepresented itself as being statistical, since the very selection of the minimum time value was itself arbitrary and the final value depended upon similarly developed charts.

Others would not take to the above proposal and it was quickly abandoned. A substantial group of time study men were enamoured with the average, for it is easily and quickly computed. One declares, "It is a statistically sound method." Others, however, recommend the elimination of the extreme values before the average is computed. But after the "sound statistical" result is arrived at, adjustments are made through leveling, grading or rating the time value on the basis of value judgments.

The polemical discussions as to the relative merits of minimum versus average attracted widespread attention and produced learned discussions. But more pragmatic "authorities" found the discussion unrewarding. The differences, they felt, were insignificant. They offered both or suggested the use of either.

Yet another group proposed the composite time formula which consisted of averaging the minimum and mean times. Still another group soon appeared advocating a modal average which automatically eliminated the extreme high and low values. They preferred this simpler procedure as it shielded them from attack on the grounds that they discarded data arbitrarily.

The advocates of these time selection systems purported that their systems were statistically sound. They reinforced their position by pointing to success in actual applications. They found ready support for their claims because management believed the time study man a valuable adjunct to organizing production systems and repressing workers' claims and objections to

standards. What better way to challenge the worker than to ask him to rebut "scientific statistical findings?" The general run of time study men were not disturbed by the lack of statistical foundation.

In time, increased acceptance of leveling and rating techniques slowly supplanted all pretense of following a statistical procedure in the selection of representative time values. As the new procedure gained sway, the terminology and jargon of the statistician was retained, but the practice of determination was radically revised. More and more the choice became a judgment process which remained related to the earlier approaches only in that the time study man still employed actual observations to guide him in his evaluation. But in fact, his decision as to the proper time values was arrived at quite independently of the statistical procedures used for the analysis of observations. (2) The climax was reached when the Society for the Advancement of Management released its rating films with the following statement: "All systems of establishing time standards are arbitrary." The alternative is to obtain the averages of a large number of ratings made by various company groups and reduce them to "a common denominator." It recommends that this result be used as a benchmark for "a day's work for the average qualified incentive operators."(3)

Rating Systems Create Theoretical "Normal Distribution"

After abandoning procedures for statistical manipulation of observed data, the time study men have wavered between two seemingly conflicting approaches. On the one hand, there is the proposal to find a one best method of doing a job and a one appropriate time value for specific physical motions. These would become standard, immutable and universal. It is reflected in such concepts as Segur's so-called "law of motion-time" which asserts that "within practical limits, the times required by all expert workers to perform true fundamental motions are constant." It finds its counterpart in the conclusions of the SAM research report which states that "there seems to be little or no regional or industry differences in concept of proper performance." A true fixed value exists and is good for all time.

The other group builds upon the assumption that within the population as a whole there is a normal fixed distribution of aptitudes and performance potentials. They do not deal with actual records; they are concerned primarily with potentials. Theoretically, it would be possible to obtain this normal distribution through studies of an infinite or carefully developed sample of representative workers under standardized conditions with the factors of motivation favoring an adequate display of the workers' potential.

Support for this approach is seemingly provided by studies of human differences, and more recently, by David Wechler's study on the "range of human capacities" (4), which suggests that human physical capacities are distributed on a bell-shaped curve with a range of roughly 1:2.25.

But in applying these assumptions, the proponents encounter some difficulties. First, tests and data for the entire population do not exist. Second, they are dealing with the potential and not the actual performance, for which adequate experimental methods have not yet been devised. Third, their immediate responsibility is to obtain a standard time value for a specific job and not the full distribution. As a result, these exponents of rating arrive at practically the same point as the preceding group in that they posit the existence of a universal distribution. Their study of an actual situation is intended only to provide guidance for the selection of either the normal which one author places at the 1.23 mark on the range scale or the incentive level which supposedly lies at the 1.6 gradation. The minimum and maximum range calibrations are 1 and 2.25 respectively. Since the observations cannot furnish them with any specific definable point on the distribution, they are under the obligation to select it on the basis of their own judgment and mental image of a normal distribution of potential performance. (5) Every claim to the use of a statistical procedure falls by the wayside. The standard value becomes the equivalent of Segur's constant time value.

The proponents of predetermined time standards have merged the two ideas. They have developed semantic motion descriptions and provided certain constant time values for the performance thereof. The individual practitioner selects the motion definitions he thinks the system's developers would have applied to the observed phenomenon and credits the standard time allowed therefor. The time values themselves are the product of traditional time study techniques, but they are being sold as universal values. In the course of being transferred from the jobs and observers employed in deriving the tables to entirely different job situations and different observers, they become even less satisfactory than direct observations.

The original observed data from which the standard allowed times for one system were derived were first plotted on graphs. The compilers of these data concede that, although speed rated, the points did not make a smooth curve and the positions on the final master curves were merely estimated by the draftsman. The inventors of the system assume that all observations deviating from the hoped-for smooth curve do so because of "rating errors" or chance fluctuations. No statistical evaluation of these

claims is made nor is one possible in view of the arbitrary nature of the reference data.

Two pragmatic illustrations of "guide" performance are usually paraded before students and the public to lend an air of reality to this entire procedure. We are told that soldiers are supposed to march at the rate of 3.64 miles per hour and that card players dealing a full deck into four hands should require only .45 minutes. But even these time values are disputed by others, who propose that the average worker should walk 3.9 miles per hour and deal fifty-two cards in .23 minutes. Different time standards for these very activities have been quoted by other practitioners.

Some proponents have attempted to lend credence to these "guide" normals through application of correlation theory. Starting with a select group, such as young men of military age, they observe and record walking rates which are later treated as a random sample of the entire population. The sample is subsequently "fit" to or correlated with a normal distribution ostensibly establishing that the walking rates of the population at large are normally distributed. Even if true, this information would have little value as the time study man is searching for an "effort" rather than a walking rate distribution. Meaning is ascribed to this curve by introducing the concept that the difference in speeds is ascribable to differences in "effort," skill, or some other characteristic seemingly within the observee's control. Time study devotees refuse to acknowledge that the mere appearance of a correlation tells nothing of a cause and effect relation, or more, that numerous cause and effect relations often may be postulated on the basis of single correlation pending further evaluation by a priori reasoning. In the case of walking speeds, for example, it appears at least likely that the observed distribution of walking rates may correlate with and be ascribed to the distribution of leg and stride lengths among observees.

These time study men are confronted by a truly challenging task. In making a specific study, they first have to compensate for the limitations of the sample of persons whom they study. Generally they study only a small number of the workers employed on a specific job and these very workers are themselves highly selected persons. The selective results of the hiring process are supplemented by turnover stemming from personal choice dismissal procedures. The established work force obviously represents only a very limited segment of the distribution. In the second place, the observer must be able to distinguish between potential and actual performance. Third, individual deviations due to variations in skill, consistency

and effort or differences in methods must also be discerned. Fourth, they must allow for the differences in anatomy, physical differences, reaction times, emotional responsiveness and the conditions in the specific work shop.

As fundamental a problem is the increasing recognition that the very assumption of constants in human aptitudes may have to be seriously modified. It is a commonplace to recognize that favorable environmental conditions, good food, appropriate education and kind parental attention have advanced the human potential in our current generation over that of its predecessors. As our economic wealth, social institutions and knowledge improve, further gains can be expected. Similarly, increased medical knowledge, shorter worker hours, and better living conditions have helped delay senescence, preserving high human potential into the older years. Already evidence accumulating from longitudinal studies, as contrasted with cross sectional studies upon which our past knowledge is founded, suggests that earlier conclusions on constants do not fully account for the improvements in human performance or adequately measure the characteristics of the older persons. The industrial engineer has built on assumptions which current psychological and physiological research is challenging most seriously.

If the time study man's procedures relating to motion time values bear no resemblance to a statistical procedure, we might have expected that his handling of the physical job characteristics would take cognizance of the demands of good statistical methodology. But here again, an arbitrary approach has been used. The common practice has been to specify desired operating conditions rather than the prevailing one. This deficiency is particularly evident in the textile mill, where variations in room, machine and atmospheric conditions, materials and processing have a marked effect on the frequency of the occurence of job duties. Instead of formulating inferences as to the distribution, time study men have used rigid standard frequencies in a manner comparable to that employed to derive fixed element time values. The resulting product is unrepresentative of reality.

The time study man's own cynical view of the meaningfulness of his inferences is highlighted by his conduct in the administration of standards. Although he hypothesizes that a normal distribution characterizes the sample, he has little tolerance of variations in output among workers and not infrequently, he will propose dismissing employees who fail regularly to perform at his incentive level. On machine-paced tasks he insists upon assigning all workers the maximum "incentive opportunity" machine complement, virtually compelling performance at high levels

despite acknowledgement that potentialities are normally distributed. Where the worker fails to keep abreast of job demands the disruption becomes apparent and the low producer is made conspicuous. If the worker requires make-up pay to provide him with his guaranteed minimum, he soon becomes the object of ridicule, for the time study practitioner insists upon employing the incentive standard as a test of desirability rather than a point on a statistical distribution. Low producers are rarely viewed as representatives of the probable population segments below the mean but, most frequently, are condemned as undesirables who insist on withholding production.

In actual practice, the time study man's statistical jargon is adopted merely to endow his presentation with a mathematical veneer. The basic procedure is merely a rationalized methodology for judging the potential of production levels within a plant. The practitioners of the rating or leveling techniques have abandoned every attempt to build on observed data and merely retain a conceptual framework of statistical terminology within which they explain their mental processes for selecting time values. They are unwilling to accept the restraints imposed by the procedures for statistical inference, since these restraints would cripple the observer's ability to make his answers coincide with his judgments. Yet he is bound by tradition and convenience to continue to employ the statistical concepts. As a result, he is constantly enmeshed in a web of contradictions from which he cannot be extricated.

Statistical Techniques for Developing Time Values Unsuitable to Management

The recent proposals for and illustrations of the use of statistical quality control techniques in the development of time values illustrate why management finds statistical techniques inadequate.(6) These procedures require that a production process be stabilized. Then, if consistently high producers are assigned to a job, "precise estimates and predictions" can be made of future production (optimum) performance on the job. It relies completely on actual observations and eliminates much of the subjectivity found in the normal time rating procedure. Judgment is kept to a minimum as the analysis is limited to a statistical evaluation of the information actually obtained.

But time study men have noted two basic objections to the technique. First, it has made abundantly and indisputably clear, if any additional clarification were necessary, that the current time study art is not a valid statistical inference application. Second, it cannot serve management in defining potential production. It can, at best, only describe optimum performance in

terms of present application levels. It is a sound reporting approach, but provides no key to the possibilities of raising the level of application on which management's basic interests are centered. It can describe actual but not potential human application. Its very adherence to statistical procedures restricts its prognostic powers and therefore, in management's view, defeats its purpose - to provide a "scientific" rationale for raising levels of application.(7)

Statistical Procedures Must Be Introduced
Where Measurable Objective Data Are Available

The appraisal of statistical procedures in industrial engineering must recognize that a determination must be made as to whether a specific phenomenom is measurable, and whether objective data which are amenable to statistical treatment can be assembled. Where either the phenomena are not measurable or objective data cannot be obtained, then statistics has limited functions to perform. In evaluating procedures such as are common with respect to employee rating or job evaluation, statistical treatment of the data cannot bring validity or reliability to the conclusions or findings.(8)

In the actual definition of working conditions, there are many facets where we have to rely solely on judgments and evaluations rather than the procedures of statistical inference. The determination of the condition of machines, the cleanliness of a room, the adequacy of wall colors, the fatigue induced by jobs are all matters of personal appraisal which are not likely to be measurable for some time.

The great challenge to all industrial engineering is to create measures of phenomena and to provide instruments or methods of obtaining objective data with these measures. In the most important area of time study, namely motion times, we have not yet achieved the first objective. Many systems of predetermined standard times for defined motions have been developed, but we are still without adequate knowledge of the various dimensions of a motion. We cannot adequately define a standard motion or produce scales through which reproduction and gauging of variations is possible. A human motion is not a simple mechanical act. It involves complicated physiological, chemical and emotional processes. An adequate description would embrace the muscular and mechanical phases of the preliminary movement, the act and the follow-through. Beyond biomechanical phases, there are chemical, neurological and emotional facets which must be included. Individual differences must also be considered in any such description. But most fundamental, we have not yet established precisely what constitutes a reproducible movement and what range of variations among individuals we must expect.

There are areas in job description for which we have measures and where we can obtain measurable data. These relate to such matters as machine speeds, frequencies of work duties, temperature and humidity, room layout and material and product characteristics. There is no reason for not applying statistical procedures to these phenomena. As a matter of fact, the quality control men have made considerable progress in advancing their measurement of these phenomena, but the time study practitioner has been most backward and reluctant to incorporate them in the art of setting job specifications.(9) Significant contributions can result from this technique in defining stable conditions and maintaining them and we have earnestly urged such advances upon the profession.(10)

The use of statistical quality control techniques in determining whether job conditions are sufficiently stable to be studied would, in itself, greatly reduce the conflicts which are often generated by the application of standards. It can be of further use in helping to keep close to the stable conditions assumed by the specification.

One major defect in the traditional time study procedure has been the slovenliness it encouraged in the application. Workers' complaints that actual frequencies of work duties exceeded those stated in the specification were met with a shrug of the shoulder. Discontent and unrest were the result. With continuous checks by statistical quality control techniques, the maintenance of the standards becomes routine, departures are regularly observed, corrections initiated, and allowances automatically provided. The adoption of these procedures by industrial engineers would do much to dispel the animosity they have aroused. The initiation of such techniques will also provide a readier understanding of workers' grievances against standards which now are often rejected because the engineer's tools are inadequate to the task of discerning the true meaning of the complaint.

The Impending Ascendancy of Statistical Procedures in Managerial Decision-Making and Its Growing Impact on the Communal Environment

Reliance upon statistical inference in the solution of industrial problems has recently surged ahead with the adoption of operations research techniques. The operations researchers themselves are true industrial pioneers, scientists who are for the first time bringing science out of the laboratory into the business world. The goals differ from those of the time study man as qualitative appraisal is assiduously avoided. They differ from those of the quality control man as their aim extends beyond objective

reporting. Operations researchers seek mathematically to define the optimum or ideal, even though, in practice, they may not expect to attain it. The practitioners have been acutely aware of the differences between their philosophy and methodology and that of their predecessors. They have made conspicuous efforts to disassociate themselves from the industrial engineers, apparently on the theory that industrial engineering is synonomous with time study and association with the latter is beneath the dignity of science. However, under whatever title they may adopt, operations researchers will doubtlessly expand their domains and increase their influence. If they do not absorb the industrial engineer they will share many areas in common. A discussion of their procedures is pertinent here.

The need for distinguishing measurable, objective data from evaluations will be increasingly important with the growing use of the advanced applications of statistical inferences. They require the consideration of alternative assumptions to determine the reasonable attractiveness of various possible solutions. In these procedures, the industrial engineer or the operations research practitioner is aware that the judgments must be made by an outside authority and these are values which he cannot control. Similarly, he must make clear what these values and considerations are and who has made the judgment, because, insofar as they directly affect workers and in many cases where they have only an indirect effect, these must be subject to collective bargaining. The advance of the operations research techniques makes it even more important than ever before that all value judgments used in the advanced calculations be carefully spelled out.

The trade unionist's concern with operations research is of the same character as that which originally was evidenced respecting time study. The practitioners are primarily physical scientists, or if the industrial engineer finally enters the picture, engineers. They have little schooling in or sensitiveness to the human effects of their analysis. The social adjustments which may be required tend to be overlooked or dismissed in the name of the so-called greater good -- higher industrial efficiency and lower costs. This attitude cannot but continue to increase the tensions in industrial relations. The operations research practitioner must increasingly absorb these considerations into his calculations in order that the full cost and the full measure of the adjustments be known.

The operations research man in his native environment, the university research laboratory, was concerned primarily with the physical factors. But our industrial activities have matured to such a degree and taken on such large proportions as to make virtually every non-routine move a matter of social concern.

Changes in inventory policy, shipping procedure, or plant and warehouse location may seriously affect the lives of many thousands of individuals and the economic welfare of an entire community. The operations research man must not omit these cost factors from his speculations as it is entirely conceivable for him to effect decisions which are more sweeping than those of the time study practitioners. His results should be concerned with social impact even more than were those of the time study practitioner.

The operations researcher's work has become no less a social concern than that of the nuclear physicist. In accepting the function of guiding executive decisions, he is automatically investing himself with the moral obligation of concern for the public interest, and to fulfill this obligation, he must develop his competence beyond achieving statistical agility into an interest in community and labor relations. Before reporting to the executive echelon, he should be prepared to make his data, assumptions and inferences available to the bargaining agent. He is under a moral compulsion to consult with the trade union on alternative assumptions in his calculations, to increase the probabilities of investigating all alternatives and achieving the most socially desirable result. This obligation must continue through the preparation of the report for executive management. He must emphasize these alternatives in his presentation to management, lest decision-makers seize on seemingly least complicated solutions which overlook the factors of human and social well-being to the exclusion of an almost equally satisfactory result which may be obtained while protecting these interests. He must be prepared to disclose all his assumptions and his projections to both parties, rather than serve to rationalize management's prejudices. Operations research demands more than mathematical competence. Each extension of its influence carries with it new responsibilities. Scientists concerned with operational problems cannot accept the burden of analysis and reject all responsibility for decisions.

Operations analysts have a special responsibility to avoid succumbing to the glib assurances of high powered salesmen offering neatly packaged panaceas for management problems.

Officials of a firm marketing one standard data plan recently sought to dovetail distribution of their product with the application of operations research methodology to the prediction of labor costs in construction, electrical repair and mechanical maintenance work. The proposal built upon the assumption that the time data provided "universal standards for work ranging from carpentry repairs to construction of a factory."(11) The proposed program further presumed that it is possible to

select "the best workers for various jobs." But, as we previously noted, there are no measures of human movement much less objective time standards to assign to them. Moreover, there are no reliable measures through which the "best workers" may be sorted out with any degree of assurance. These two crucial elements of final cost estimate would not be factual, but rather human, judgments on which a wide variety of opinions may prevail. The operations researcher must recognize them as such and permit the collective bargaining process to work out acceptable conclusions. In addition to restraining himself from making convenient assumptions, the operations researcher must make apparent to the parties the inherent hazards of their approach. Thus, even if the parties were able to recognize the "best workers" among the population of workers at large, the analyst's duty extends to informing them of the probabilities of finding sufficient numbers of such people to fill their needs and the probable cost society would incur if employment opportunities were restricted to an elite group of craftsmen. Many other similar social and economic issues must be weighed.

Conclusions

Industrial engineering has progressively flirted with statistical concepts, abandoned them and retained the jargon, and adopted probability formulations in the solution of an ever-widening sphere of problems. The trend away from judgments and toward scientific inference has been the direct result of newly developed interests in broader managerial problems other than work measurement. Where complex random interrelations are governing and the worker is unable, even by extending himself, to overcome the obstacles impeding operation at the desired optimum efficiency, industry is faced with the alternative of burdening itself with the inefficiency or utilizing scientific research methods to resolve the problem. As long as the time study man was in command, he tended to restrict analysis to the worker and to rely upon the worker's flexibility to overcome the deficiencies of his craft. Beyond fostering misunderstanding of the procedures of mathematical exactness, statistical inference was not recognized as a useful tool by the practising fraternity.

The very nature of the scientific approach contrasts with that of the time study man in that it views the enterprise as a complex interrelationship of numerous dynamic factors. As a result, the scientific practitioner is prone to undertake the formulation of inferences of sweeping import. Attention will be focused on the scientist and the statistical tools upon which he extensively relies. These practitioners must be alert to the fact that the enterprises on behalf of which they apply

their skills are business ventures, and that while problem-solving is a fascination for the scientist, it is a monetary concern for the industrialist. The pursuit of monetary goals is the legitimate goal of the industrialist but the approach selected must be consistent with broader social standards, including the well-being, both in immediate and long terms, of the communities, the nation and the people. The complex character of many operations research analysts tends to obscure, even from the practitioners, the dangers inherent in the implementation of certain decisions. The professional integrity of the operations researcher is, therefore, constantly at stake. At the very least, he may undermine the morale of the work force and create an atmosphere in which it will be difficult to introduce subsequent changes. An appreciation of the legitimacy of labor's concern with their studies is an essential for those who choose to serve the economy as members of operations research teams. They must be as concerned with the human and social consequences as the nuclear scientists are concerned with the effects of their discoveries and inventions. Their calculations must include the factors of personal and social cost so that they may be weighed and kept to a minimum in this age of sweeping change.

FOOTNOTES

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NOTES

"MATHEMATICAL CHARACTERISTICS OF PERFORMANCE TIMES -- A PRELIMINARY REPORT"

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We have been requested to discuss the general topic of "Research in Time Study" and, specifically, to tell you a bit about one of the long range fundamental research projects we have been conducting at Georgia Tech. As you may know, we have had a very active Industrial Engineering program at Georgia Tech for the past nine years. We also have had a very active Engineering Experiment Station working on industrial and government research projects. Some of the funds accrued from these Experiment Station projects and Graduate Division research grants were used to finance the project we are about to summarize for you. During 1950 and 1951, we undertook to evaluate the statistical and mathematical developments in work measurement. Our conclusions indicated that there was considerable need for the development of a better understanding of the fundamental phenomena associated with performance times. We were led in this direction by the paucity of work being undertaken on this behalf -- most investigative work had been concentrating on the "practical" gimmicks associated with time study without any real efforts being directed toward the more fundamental aspects of the problem. (Dr. H. O. Davidson's work is a notable exception and an encouraging point for our own work).

Our original objective was to study the mathematical characteristics of performance times on a short-cycle manual

operation in order to determine if there is a mathematical basis for work measurement. This was a long range objective. The immediate objectives were to gain a better understanding of how cycle times vary from cycle-to-cycle and during a work day. This project has been underway during the past four years, and it is not yet complete. We anticipate releasing a detailed report of progress to date later this year. We would now like to outline a sample of our work. But first we want to acknowledge the contributions made by Dr. Edward H. Loveland and several graduate students. Warren Lind, George Taft, Paul Friedman, Robert McLeod, Frank Summers, Herbert Wilson, and E. W. Green have all worked diligently on various parts of the project, and they have our sincere thanks.

THE OPERATION

The operation selected for study was the assembly of a ball-point pen in the Scripto plant in Atlanta. This operation was selected for several reasons:

1. The operation was short,
2. It was manually controlled,
3. It was highly repetitive,
4. The volume was high,
5. A rather large number of operators were employed on the job (about 18 to 20),
6. All operators used very similar motion patterns in performing the job, and
7. The operators all worked quite diligently -- not because they were forced to, but because they wanted to.

The relations within this plant, and in this department in particular, were excellent. The employees typify very desirable workers. Their usual level of performance was well above "normal".

DATA

A preliminary observation was made to determine the general work pattern variations. This study involved observing each operator on each shift for six to eight periods; during each observation period, 25 cycles were timed; 19 operators were observed; times were obtained by a split-hand time study watch; detectable methods variations were noted.

The results of the stop watch observations were used to plan a movie observation of the job. 15,000 feet of 16 mm film were taken at 2,000 frames per minute. Approximately equal amounts of film were taken of each operator, in observation

periods of two-minutes each throughout the work shifts. These films were analyzed frame-by-frame. All gross changes in method were eliminated. Minor methods changes were identified and classified.

WORK CURVES

Results for one operator, selected at random from the group, are presented in Figure 1. This operator, Q, was working on the third shift -- from 11:30 P.M. to 7:00 A.M. The variation in average cycle time seems to follow the typical work-curves referred to in many texts. However, this pattern was not confirmed by the other 18 operators. In fact, no general pattern was evident.

The data in Figure 2 shows the same operator for the film study. The cycle has been redefined to exclude the last portion of the job cycle related to asiding the finished assemblies. This was done to give a more adequate methods comparison from operator to operator -- but that is of little importance at the moment. The work-curve shows a general downward trend.

Figure 3 presents the same information with the minor methods variations removed. The pattern is still similar.

The results so far tend to indicate that there is no typical work-curve for the operation studied.

STABILITY

The next analysis was to evaluate the stability of operator performance times. This was done in two manners. First, by a control chart analysis, and second, by an analysis of variance. Both analyses indicate that Operator Q is generally stable. Again, however, the other operators do not give similar results.

Of the 19 Operators included in the stop-watch data, 9 indicate some lack of stability by control chart analysis. This analysis was performed by using X-bar and sigma charts, with sample sizes of 5 and 25.

The control chart analysis of the film data with minor methods variations included indicated 6 out of 19 operators as lacking stability. The sample size ranged from 3 to 14.

The control chart analysis of the film data with minor methods variations removed indicated 5 out of 19 operators as lacking stability. The sample size ranged from 2 to 12.

The three control charts for Operator Q are presented in Figures 4, 5, and 6.

The analysis of variance, which compared the between against the within observation period mean squares, indicated that Operator Q lacked stability in the stop-watch data but displayed stability in the film data under both conditions.

From the analysis of variance studies, 11 out of 19 operators in the stop-watch data lacked stability; 8 out of 18 operators lacked stability in the film data with minor methods variation included; 3 out of 18 operators lacked stability in the film data with the minor methods variations removed.

The general lack of stability of operator performance, as measured by the control chart analysis and the analysis of variance, can be interpreted in several ways. It may well be that the criterion of stability, as measured by the control chart and the analysis of variance, is inappropriate for the phenomena being studied. Changes in operator level of performance occur more noticeably between observation periods than

within the periods. It may be hypothesized that when considering the true nature of the overall work-time distribution, there is a definable random variation in operator level of performance that should be considered along with variations of a chance nature that comprise the short period variance. The lack of stability may also indicate that some shifting in level of performance could be caused by factors beyond the control of the operator (such as parts variations). It is possible that some operators were "pacing" themselves. Further, it is possible that some of this instability was caused by lack of complete skill. However, these things were not detectable from the film analysis, and all operators had sufficient opportunity to completely master the job and were considered by the company to be well qualified.

The control chart analysis and the analysis of variance were executed to take advantage of their different statistical characteristics. However, in many cases the results were similar. The control chart was effective in detecting lack of stability in the form of isolated large shifts in performance level (points outside of the control limits) and in detecting "runs" caused by infrequent shifts in the performance level. The analysis of variance was quite effective in detecting the latter type of instability but not the former. In addition, it was most useful in detecting frequent small shifts in the performance level. It was not possible to detect cycles or samples containing minor methods variations (assignable causes) by the control chart analysis. This lead to the hypothesis that there is a masking effect of increased speed in the execution of motions following the minor methods variations to the extent that these extra

motions did not directly affect the total cycle time.

WORK - TIME DISTRIBUTIONS

The data from each operator was analyzed to determine the pattern of variation for the cycle times. Histograms were plotted, moments were calculated (mean, variance, skewness and peakedness). These results indicated quite clearly that the normal or gaussian distribution did not adequately describe the work-time distributions. These distributions were markedly skewed to the right, and they were somewhat more peaked than the normal curve. This has led to the hypothesis that the time for performance does not bear a linear relation to difficulty of performance. In other words, it is much easier to increase the performance time one unit than it is to decrease the performance time one unit. Stated another way, there is a physiological (and maybe also a psychological) lower limit for a specific operator, but there is no practical maximum limit. This hypothesis would indicate that under statistical laws, if only chance factors influence variations in performance times, the resultant work-time distribution should be skewed to the right. there seems to be support for this inference in light of the skewness remaining evident even after minor methods variations were removed from the film data.

CURVE FITTING

The work-time distributions were subjected to curve fitting to determine if they did tend to follow any particular pattern. The normal curve did not adequately fit the data. The log normal curve (x axis on a logarithmic scale) fitted reasonably well, as did the Pearson Type III curve. Of the curves tested, the

Pearson Type III seems to be most descriptive of the work-time distributions. It seems likely that other curves can be developed from the parameters obtained that will do an even more adequate job of describing the work-time distributions.

VARIATION IN LEVEL OF PERFORMANCE

It was previously stated that using the measures of stability that were employed in our investigation we could infer that the operators under study did not perform in a stable manner. This led to the hypothesis that variation in level of performance was typical and to be expected as a long cycle variation of a somewhat random nature. We attempted to ascertain the magnitude of influence of this long cycle variation in level of performance. This evaluation involved assuming that the observation period mean time (25 cycles in the stop-watch data and from 3 to 14 in the film data) was our best estimate of the level of performance during the observation period, and, further, that the influence of change in general level of performance could be removed by removing the difference between these period mean times for each operator. This adjustment was made for each operator, moments were calculated, and the normal, log-normal and Pearson Type III curves were fit to the work-time distributions. The results for Operator Q are presented in Table I. The moments have changed slightly, and the chi-square goodness-of-fit values have also changed somewhat.

The results from the other operators did not indicate any particular pattern of change, but the Pearson Type III curve does appear to fit these data better than the unadjusted data.

This analysis is still underway, and these results are very intuitive, but it does seem that the adjustment will not markedly alter the skewed characteristic of the work-time distribution. A tentative hypothesis could be stated as follows: minor changes in level of performance do not by themselves cause the work-time distribution to be skewed.

ELEMENT WORK-TIME DISTRIBUTIONS

So far we have been discussing the cycle-time work-time distributions. You may wonder if the elements within the cycle vary from the pattern indicated for the cycle. We are currently investigating this for the eleven elements of the cycle. The elements were broken down into "get" and "place" groupings of therbligs.

The results so far indicate no difference in the general nature of the work-time distributions for the element times. The same skew to the right is evident.

CONCLUSIONS

The results of our research project so far lead us to agree with Dr. Davidson's statement that the normal curve does not adequately describe the work-time distribution. Our results indicate that the work-time distribution is skewed to the right, and departs significantly from the normal curve.

The investigation we have just summarized was undertaken in search of a better understanding of the system within which performance times are generated. It is our belief that much more work will be required in order to provide the theoretical understanding that must be the foundation for advancement in the areas of work study. No general or positive conclusions

can be reached on the basis of our preliminary report, but the results do indicate that there likely is a sound theoretical pattern that will explain the nature of performance time variations on activities similar to the one studied. If this is so, it will require a readjustment of many time study, methods evaluation, control and incentive concepts. At this point, it is impossible to clearly see the implications that may be involved if a true theoretical model for work-time distributions can be determined. Much more fundamental work needs to be done.

TABLE I

Probability Level - Goodness-of-fit - Operator Q

	Normal Curve	Log Normal Curve	Pearson Type III Curve
Unadjusted Data			
Stop-watch data	1.1%	6.0%	85.0%
Film data with minor methods variations included	0.8%	4.0%	15.0%
Film data with minor methods variations removed	1.0%	6.0%	3.0%
Performance Level Adjusted			
Film data with minor methods variations included	0.4%	1.8%	6.5%
Film data with minor methods variations removed	5.7%	15.0%	20.0%

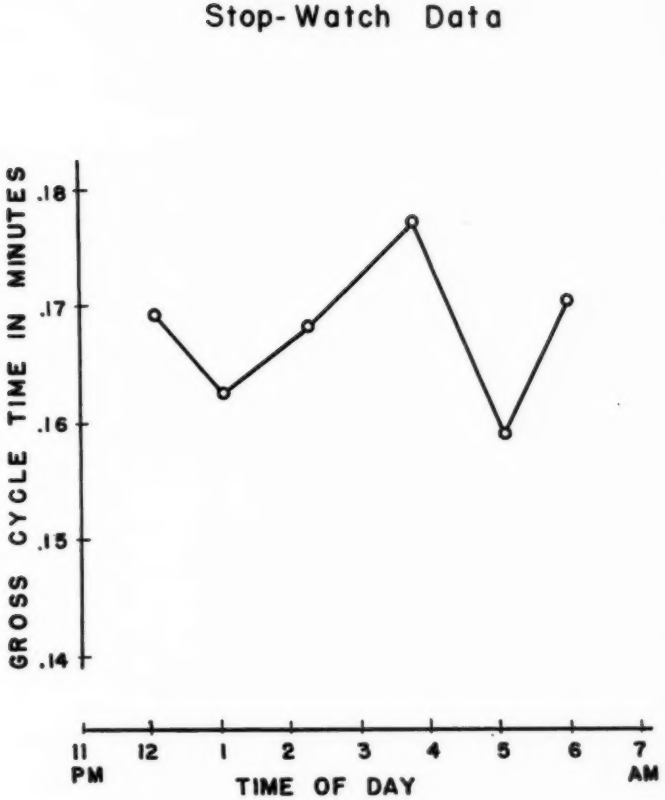

FIGURE 1. WORK CURVE, OPERATOR Q, SHOWING VARIATION IN AVERAGE CYCLE TIMES DURING THE DAY. (STOP-WATCH DATA)

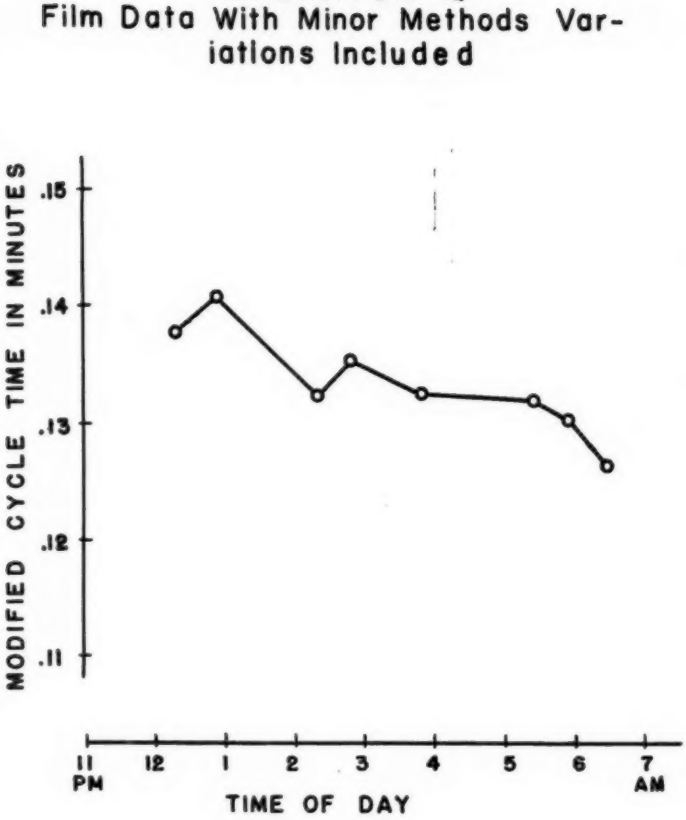

FIGURE 2. WORK CURVE, OPERATOR Q, SHOWING VARIATION IN AVERAGE CYCLE TIMES DURING THE DAY. (FILM DATA WITH MINOR METHODS VARIATIONS INCLUDED)

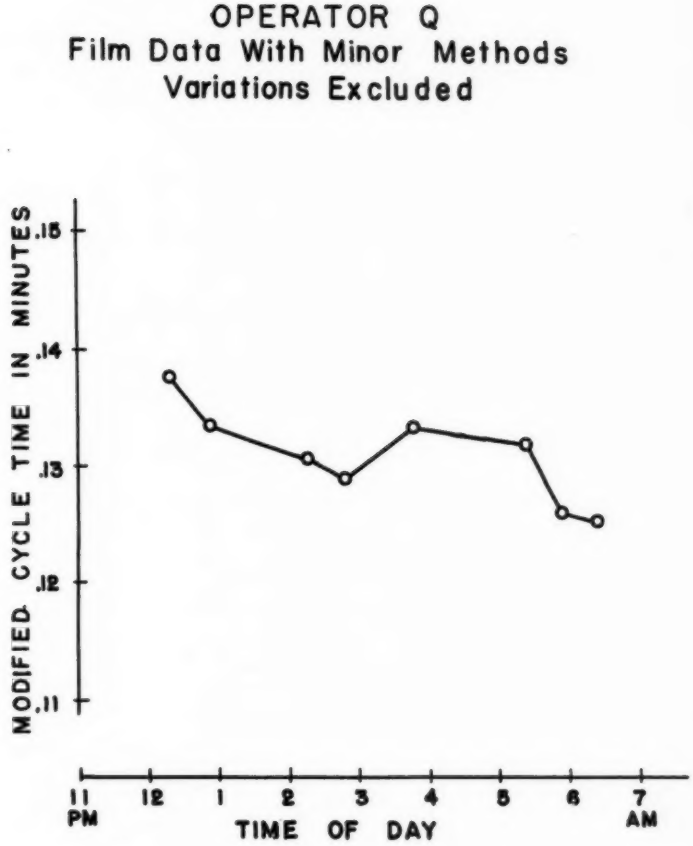

FIGURE 3. WORK CURVE, OPERATOR Q, SHOWING VARIATION IN AVERAGE CYCLE TIMES DURING THE DAY. (FILM DATA WITH MINOR METHODS VARIATIONS REMOVED)

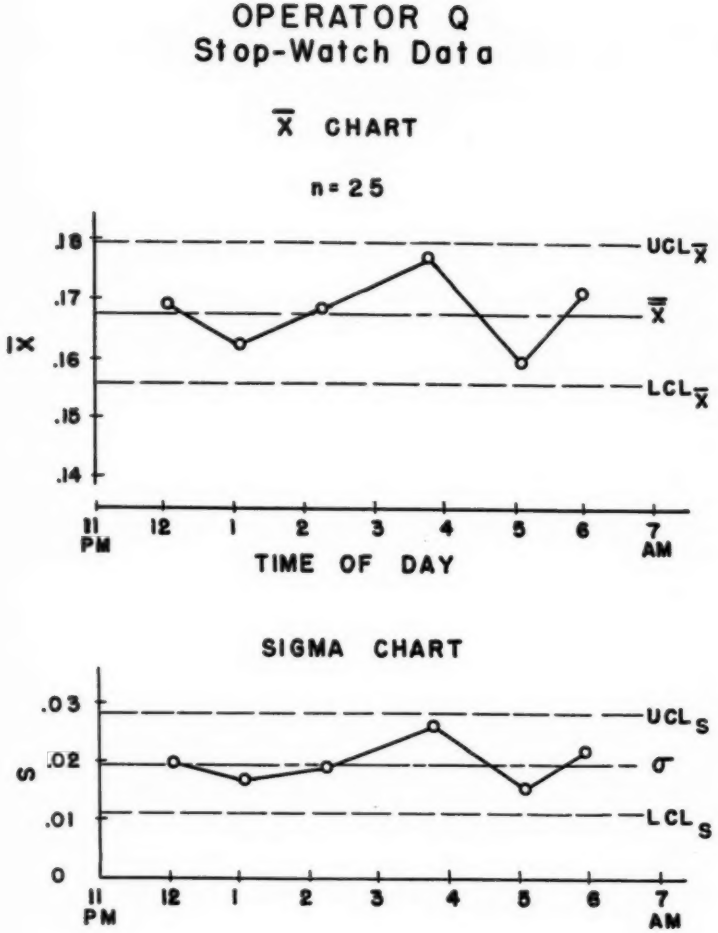

FIGURE 4. CONTROL CHARTS FOR OPERATOR Q. (STOP-WATCH DATA)

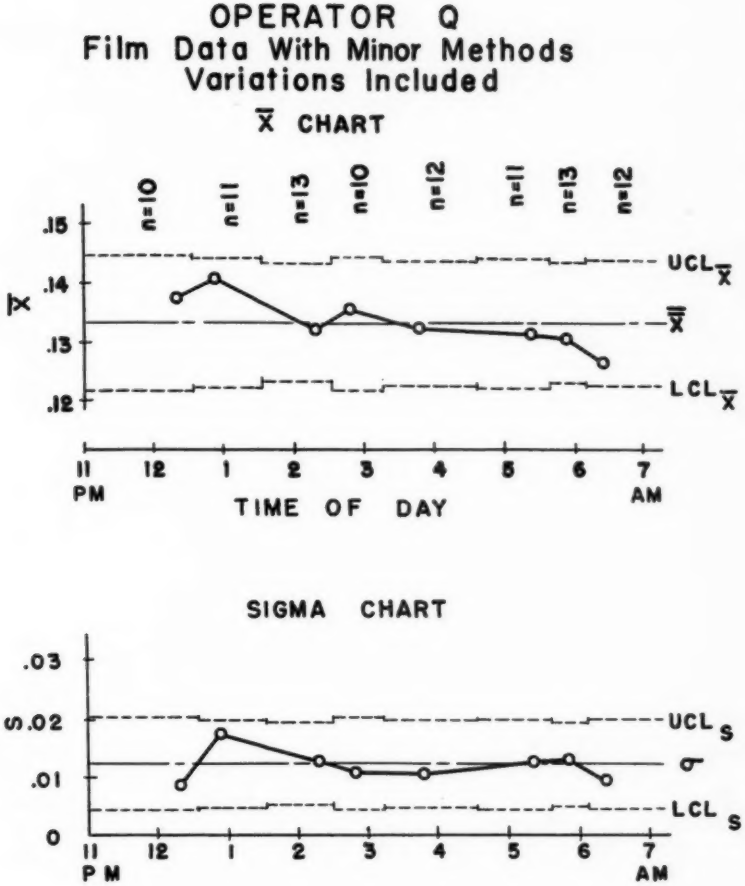

FIGURE 5. CONTROL CHARTS FOR OPERATOR Q. (FILM DATA WITH MINOR METHODS VARIATIONS INCLUDED)

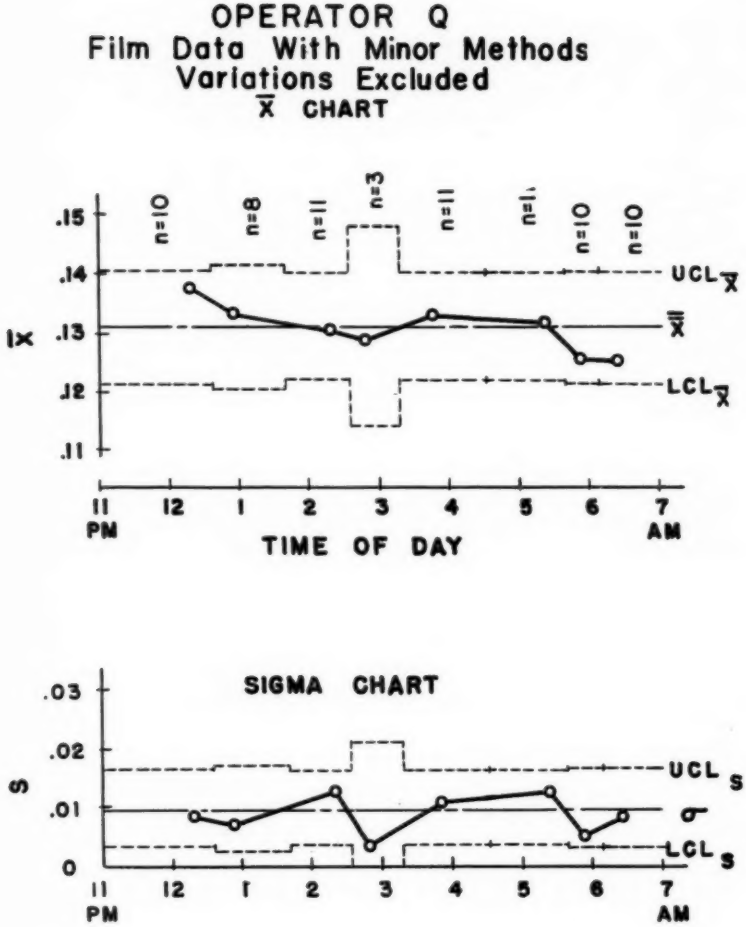

FIGURE 6. CONTROL CHARTS FOR OPERATOR Q. (FILM DATA WITH MINOR METHODS VARIATIONS REMOVED)

OPERATOR Q
Stop-Watch Data

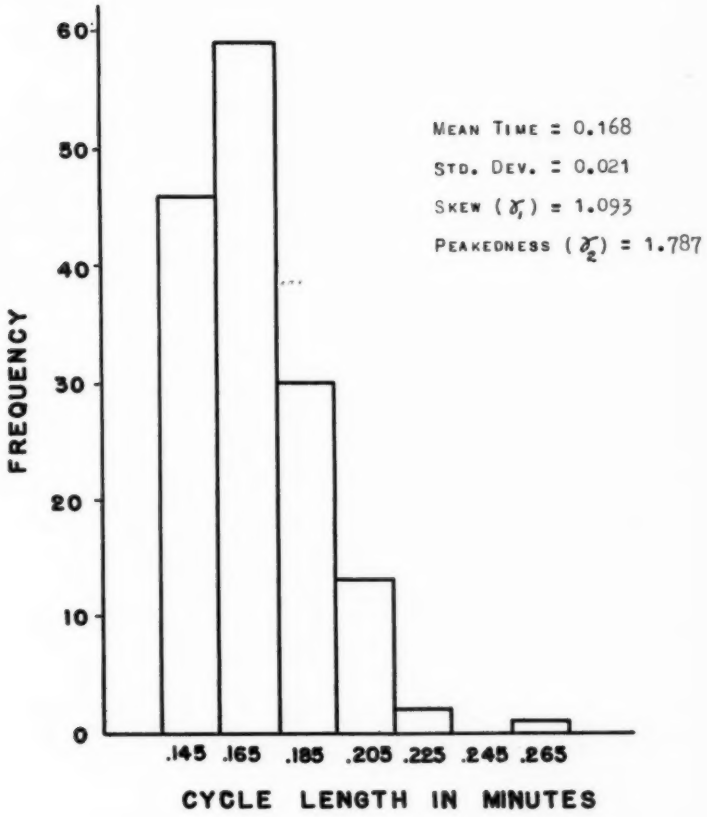

FIGURE 7. WORK-TIME DISTRIBUTION, OPERATOR Q. (STOP-WATCH DATA)

OPERATOR Q
Film Data With Minor Methods Variations Included

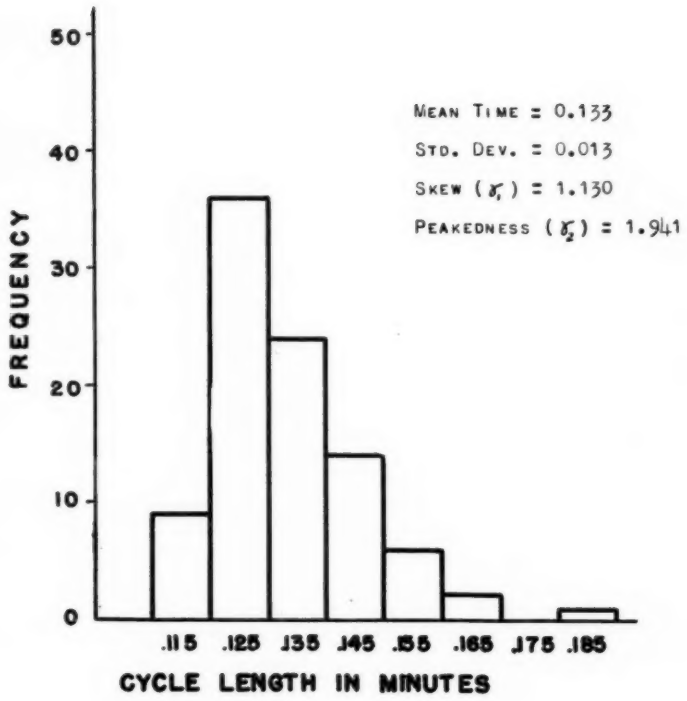

FIGURE 8. WORK-TIME DISTRIBUTION, OPERATOR Q.
(FILM DATA WITH MINOR METHODS VARIATIONS INCLUDED)

OPERATOR Q
Film Data With Minor Methods Variations Excluded

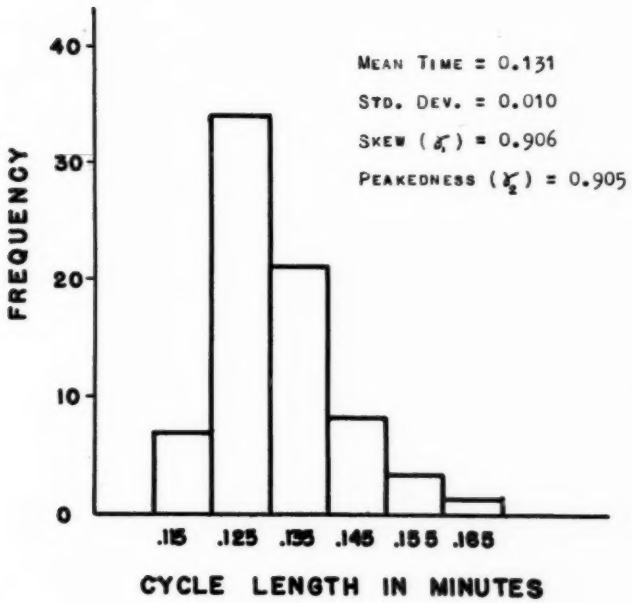

FIGURE 9. WORK-TIME DISTRIBUTION, OPERATOR Q.
(FILM DATA WITH MINOR METHODS VARIATIONS REMOVED)